Bacteria TMDL
for Falling River Watershed, Virginia

Submitted by

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Executive Summary

This report presents the development of a Bacteria TMDL for the Falling River watershed. Falling River is a tributary of the Middle Roanoke River Basin. The Falling River watershed is approximately 151,150 acres, or 236 square miles. The watershed is located within Campbell and Appomattox Counties of Virginia. Approximately 75 percent of the drainage basin is located in Campbell County; the remainder of the watershed is located in Appomattox County. The watershed makes up about 35 percent of the land area in Campbell County, and 16 percent of the land area in Appomattox County. State Highway 501 (SH-501) runs along the western boundary of the watershed in a north to south direction. U.S. Highway 40 (US-40) passes through the lower section of the watershed in an east to west direction. U.S. Highway 24 (US-24) runs along the northern boundary of the watershed in a west to northeast direction. State Highway 460 (SH-460) goes along a portion of the northern boundary of the watershed in an east to north direction.

Three segments on Falling River were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) because of violations of the state's water quality standard for fecal coliform. These three segments and a fourth segment on Falling River were also included on Virginia's 2002 303(d) Report on Impaired Waters. At the time of the Falling River listings the Virginia bacteria water quality standard was expressed in fecal coliform bacteria; however, the bacteria water quality standard has been recently changed and is now expressed in E. coli. Virginia's bacteria water quality standard currently states that E. coli bacteria shall not exceed a geometric mean of 126 E. coli counts per 100 ml of water for two or more samples over a 30-day period or an E. coli concentration of 235 counts per 100 ml of water at anytime. However, the loading rates for watershed-based modeling are available only in terms of the previous standard, fecal coliform bacteria. Therefore, the TMDL was expressed in E. coli by converting modeled daily fecal coliform concentrations to daily E. coli concentrations using an in-stream translator. This TMDL was required to meet both the geometric mean and instantaneous E. coli water quality standard.

The Falling River watershed has four impaired segments, all located on the Falling River mainstem. The most upstream segment (ID# VAC-L34R-04) begins at the confluence of the North Fork Falling River with the South Fork Falling River, and extends downstream to the mouth of Mollys Creek. The second impaired segment (ID# VAC-L34R-03), moving from upstream to downstream, begins at the mouth of Little Falling River, and extends to the Dan River, Inc. water intake. The third listed segment (ID# VAC-L34R-02) begins at the Dan River, Inc. water intake on Falling River and ends at the Brookneal Lagoon outfall. The fourth listed segment (ID# VAC-L34R-01) begins at the Brookneal Lagoon outfall, and extends to the confluence of Falling River with the Roanoke River. The total length of these segments is 10.49 miles.

Land use characterization was based on National Land Cover Data (NLCD) developed by USGS. Dominant land uses in the watershed are forested land (67%) and agricultural land (28%), which account for a combined 95% of the land area in the Falling River watershed.

Falling River flows through a predominantly rural setting, with forested and agricultural lands comprising the dominant land uses in the basin. Potential sources of fecal coliform include run-off from livestock grazing, manure applications, industrial processes, and residential waste. Some of these sources are driven by dry weather and others are driven by wet weather.

The potential sources of fecal coliform in the watershed were identified and characterized. These sources include permitted point sources, failed septic systems and straight pipes, livestock, wildlife, and pets.

An inventory of the livestock residing in the Falling River watershed was conducted using data and information provided from the DCR, Robert E. Lee Soil and Water Conservation District, NRCS, and field surveys. The data and information indicate the following:

- beef cattle exist on the pasture areas of the watershed
- five dairy operations exist in the watershed

- no poultry operations exist in the watershed
- no swine operations exist in the watershed
- no feedlots are located in the watershed
- alternative water has been implemented in the watershed to minimize livestock activity in the streams

In the Falling River watershed, bacteria source tracking (BST) was conducted monthly at three monitoring stations from December 2002 through November 2003. One station was located at the intersection of Falling River and the Route 650 Bridge (4-AFRV025.34), another at the river below the Brookneal STP (4-AFRV002.78), and the third on South Fork Falling River, at the Route 648 Bridge (4-AFSF000.66). A total of 12 sampling events were collected at each station. The human signature in samples ranged from 0 to 25 percent, the wildlife signature ranged from 0 to 56 percent, the livestock signature ranged from 12 to 100 percent, and the pet signature ranged from 0 to 54 percent.

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the in-stream water quality conditions of Falling River under varying scenarios of rainfall and fecal coliform loading. The results from the developed Falling River model were used to develop the TMDL allocations based on the existing fecal coliform load. HSPF is a hydrologic, watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineating the watershed into smaller subwatersheds
- entering the physical data that describe each subwatershed and stream segment
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

For this TMDL, the Falling River watershed was delineated into 20 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. This delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data.

Stream flow data for the Falling River watershed was available from USGS station #2064000, near Naruna. These data were used in TMDL development. The Falling River stream flow station has a period of record from 1929 to 2003. The drainage area above the station is approximately 173 square miles. Average flows of Falling River ranged from 1 to 20,000 cfs, with a mean flow of 153.44 cfs.

Weather data for the Lynchburg, VA WSO Airport and the John H. Kerr dam were obtained from NCDC. The data include meteorological data (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation). The Lynchburg airport recorded data from 1952 to 2001, and the John H. Kerr dam recorded data from 1948 to the present. For this TMDL, the recorded data at Lynchburg and the Kerr dam were combined based on their proximity to the Falling River watershed. The combined record consisted of 75 percent Lynchburg weather data and 25 percent of the weather data obtained from the John H. Kerr dam.

HSPEXP software was used to calibrate the Falling River watershed. Using the recommended default criteria as target values for an acceptable hydrologic calibration, the Falling River model was calibrated for January 1997 to December 1998. The period of January 1996 to December 1996 was used to validate the HSPF model. The validation results are presented in this report. The expert system calculates certain statistics; compares the model results with observed flow values; and provides guidance on parameter adjustment. The hydrologic calibration parameters were adjusted until there was a good agreement between the observed and simulated stream flow, thereby indicating that the model parameterization is representative of the hydrologic characteristics of the Falling River watershed. The model results closely matched the observed flows during low flow conditions, base flow recession and storm peaks.

Station 4-AFRV002.78 was sampled 46 times from 1993 to 2003. Water quality data for this station was retrieved from STORET and DEQ, and was evaluated for potential use in the set-up, calibration, and validation of the water quality model. For the calibration purposes, delineated subwatershed number 19, which contains 3 of the impaired segments (VAC-L34R-03, VAC-L34R-02, and VAC-L34R-01), was modeled and validated against delineated subwatershed number 11, which contains the listed segment VAC-L34R-04. The time period of January 1999 to December 2000 was used for water quality calibration of the model, and the same time period of January 1999 to December 2000 was used for model validation.

The existing fecal coliform loading was calculated based on current watershed conditions. Model input parameters reflected conditions during the period of 1995 to 2000. Virginia has recently changed its bacteria standard from fecal coliform to E. coli; therefore modeled fecal coliform concentrations were changed to E. coli concentrations using a translator. Water quality standards for both fecal coliform and E. coli were exceeded for the most part during this time period.

The TMDL represents the maximum amount of a pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. The MOS was implicitly incorporated in this TMDL. Implicitly incorporating the MOS required that allocation scenarios be designed to meet a 30-day geometric mean E. coli standard of 126 cfu/100 ml and the instantaneous E. coli standard of 235 cfu/100 ml with 0% exceedance.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario.

For the hydrologic period from January 1995 to December 2000, fecal coliform loading and instream fecal coliform concentrations were estimated for the various scenarios using the developed HSPF model of the Falling River watershed. Because Virginia has recently changed its bacteria standard from fecal coliform to E. coli, modeled fecal coliform concentrations were translated to E. coli concentrations, and the TMDL allocation plan was developed to meet geometric mean and instantaneous E. coli standards. Based on the load allocation scenario analysis, the TMDL allocation plan that will meet the 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous E. coli water quality standard of 235 cfu/100 ml requires:

- 100 percent reduction of the human sources (failed septic systems and straight pipes).
- 100 percent reduction of the direct instream loading from livestock.
- 98 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 50 percent reduction of the direct instream loading from wildlife.

A summary of the bacteria TMDL allocation plan loads for Falling River is presented in Table E-1.

Table E-1: Falling River TMDL Allocation Plan Loads for E. coli (cfu/year)

Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
9.05E+11	1.04E+14	Implicit	1.05E+14

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are: 1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved; 2) it provides a measure of quality control, given the uncertainties that exist in any model; 3) it provides a mechanism for developing public support; 4) it helps to ensure the most cost effective practices are implemented initially, and 5) it allows for the evaluation of the TMDL's adequacy in achieving the water quality standard.

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

The development of the Falling River TMDL would not have been possible without public participation. The first public meeting was held in the Town of Brookneal on October 22, 2003. Fourteen people attended the meeting. The following information was presented:

- listed segments of Falling River,
- the data that caused the segments to be on the 303(d) list,
- review the TMDL process;
- the livestock, wildlife, and pet inventories;
- the fecal coliform sources assessment
- the calculation used to estimate the total available fecal coliform load;
- explanation of the assumptions used in the calculations; and presentation of the HSPF model.

The second public meeting was held in the Town of Brookneal on February 24, 2004 to discuss the sources assessment, present the HSPF model calibration and the goodness of fit, and discuss the Draft TMDL. Twenty people attended the meeting. Copies of the presentation and the draft TMDL report executive summary were available for public distribution. The meeting was public noticed in *The Virginia Register of Regulations.*

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1.0 Introduction

1.1 Background

1.1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency (EPA)'s Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 2001).

The state regulatory agency for Virginia is the Department of Environmental Quality (DEQ). DEQ works in coordination with the Virginia Department of Conservation and Recreation (DCR), the Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to better develop and regulate a more effective TMDL process. The role of DEQ is to act as a lead agency for the development of statewide TMDLs. DEQ focuses its efforts on all aspects of pollution reduction and prevention to the state waters. DEQ ensures compliance with the Clean Water Act and the Water Quality Planning Act, as well as encourages public participation throughout the TMDL development process. The role of DCR is to initiate non-point source pollution control programs on a statewide level through the use of grant money. DMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits from industrial and mining operations. Lastly, VDH monitors waters for fecal coliform, classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of contamination (DEQ, 2001a).

The Clean Water Act requires every state to develop a list, referred to as the 303(d) list, of impaired waters that details the pollutant(s) in violation and the potential source(s) of each pollutant. The Water Quality Monitoring Information and Restoration Act was passed in 1997 by the Virginia General Assembly to guide DEQ in creating and implementing TMDLs for the state waters on the 303(d) list (DEQ, 2001a). Virginia's 2002 303(d) report lists Falling River as impaired for fecal coliform.

As required by the Clean Water Act and the Water Quality Planning and Management Regulations, once the TMDL has been developed, it should be distributed for public comment and then submitted to the EPA for approval.

1.2 Impairment Listing

Three segments on Falling River were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) because of violations of the state's water quality standard for fecal coliform. These three segments and a fourth segment on Falling River were also included on Virginia's 2002 303(d) Report on Impaired Waters. Water quality monitoring samples from station 4-AFRV017.71, which is located off Route 600 below the Brookneal STP, failed to attain the primary contact designated use in 3 out of 22 samples.

Falling River is located in the Middle Roanoke River Basin in southern Virginia (Figure 1-1). The watershed is located in the hydrologic unit (HUC) 03010102. Falling River runs through Campbell and Appomattox Counties of Virginia, and is a tributary of the Roanoke River.

There are four impaired segments in the Falling River watershed; all located on the Falling River mainstem. The most upstream segment (ID# VAC-L34R-04) begins at the confluence of the North Fork Falling River with the South Fork Falling River, and extends downstream to the mouth of Mollys Creek. The second impaired segment (ID# VAC-L34R-03), moving from upstream to downstream, begins at the mouth of Little Falling River, and extends to the Dan River, Inc. water intake. The third listed segment (ID# VAC-L34R-02) begins at the Dan River, Inc. water intake on Falling River and ends at the Brookneal Lagoon outfall. The fourth listed segment (ID# VAC-L34R-01) begins at the Brookneal Lagoon outfall, and extends to the confluence of Falling River with the

Roanoke River. The total length of these segments is 10.49 miles. Figure 1-2 is a map depicting the listed Falling River segments.

Figure 1-1: Location of the Falling River Watershed

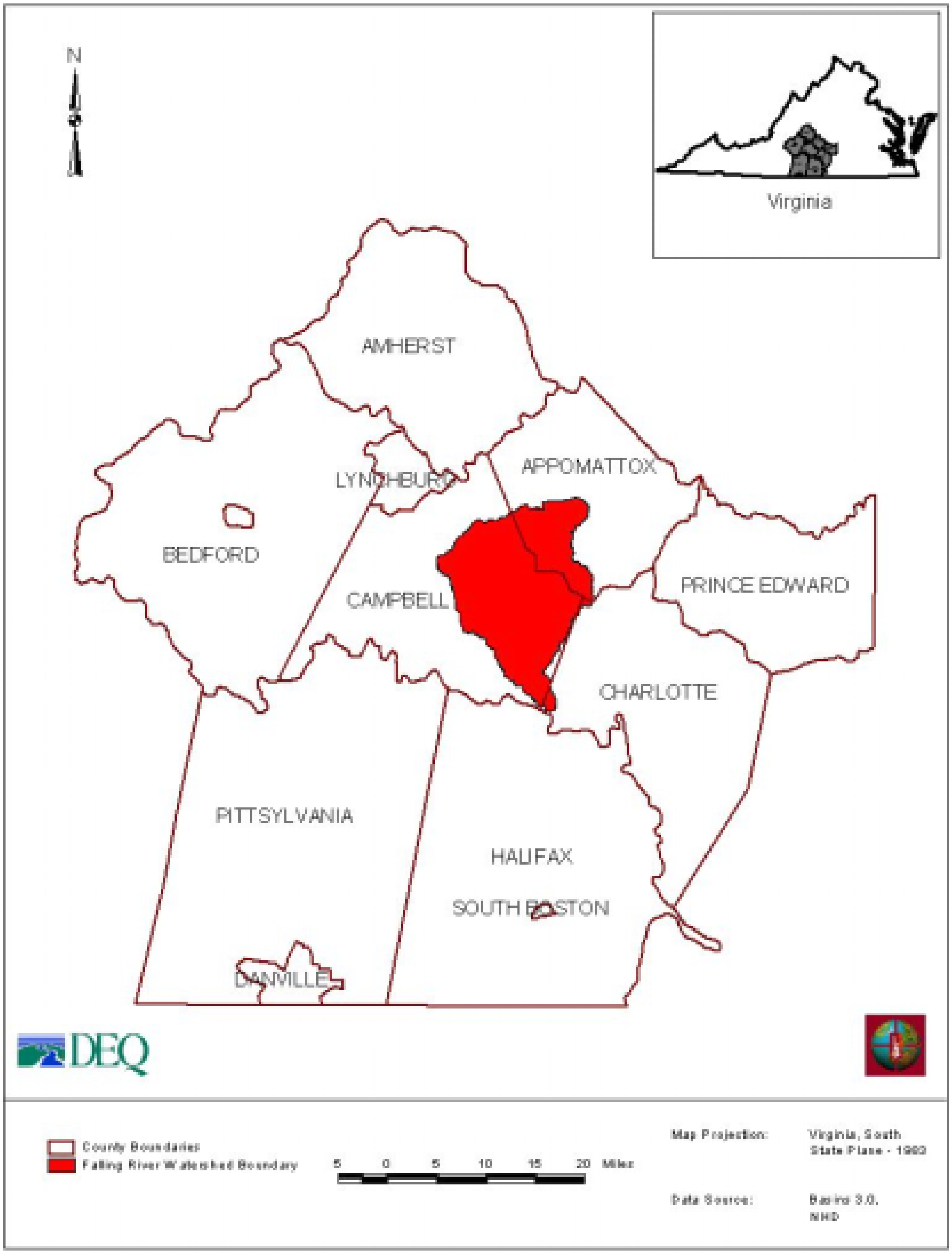
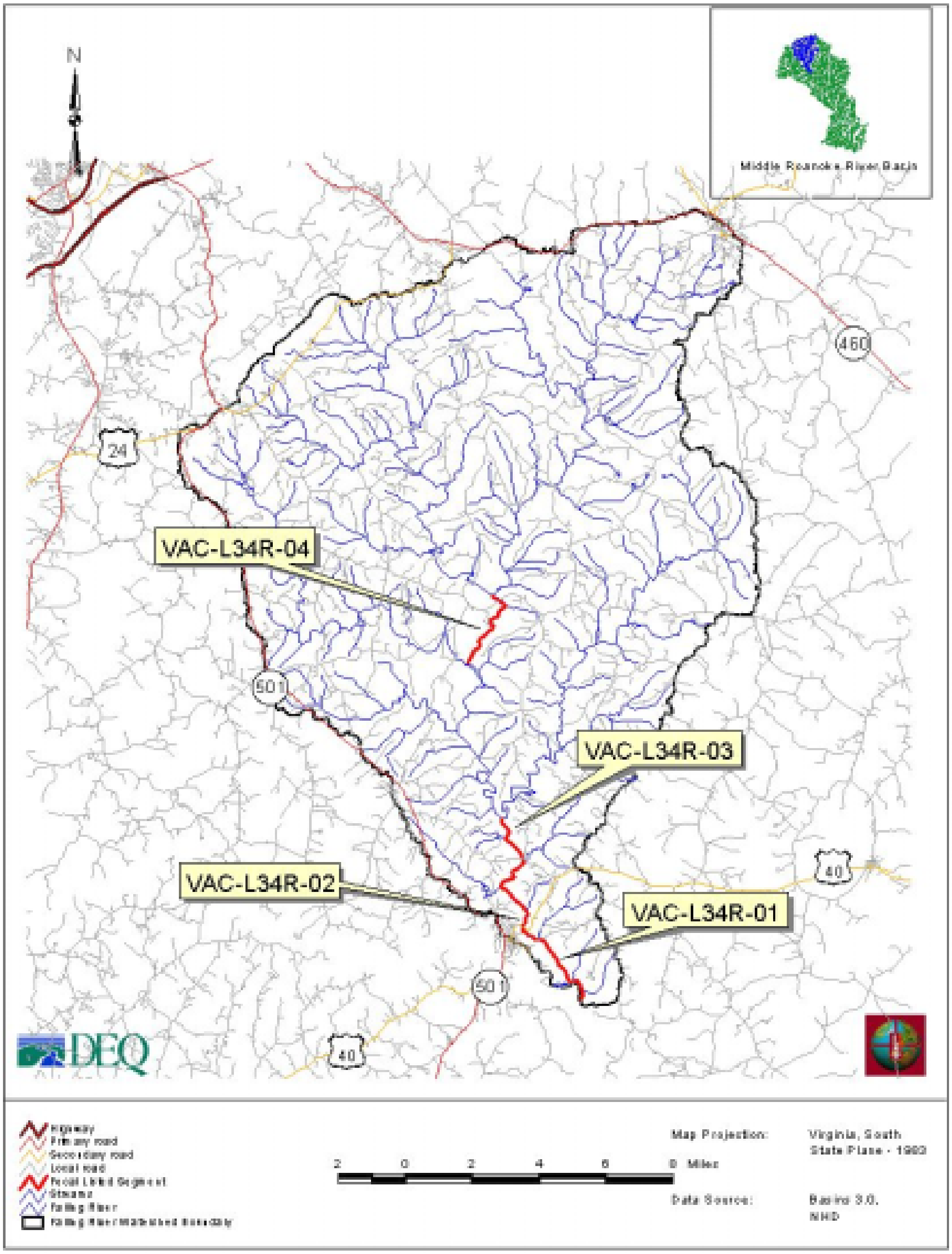


Figure 1-2: Falling River Watershed Listed Segments



1.3 Applicable Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

1.3.2 Applicable Water Quality Criteria

Effective January 15, 2003, DEQ specified a new bacteria standard in 9 VAC 25-260-170.A, and also revised the disinfection policy in 9 VAC 25-260-170.B. These standards replaced the existing fecal coliform standard and disinfection policy of 9 VAC 25-260-170. For a non-shellfish supporting waterbody to be in compliance with Virginia bacteria standards for primary contact recreational use, the current criteria are as follows:

> *"Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples taken over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the bacterial indicators have minimum of 12 data points or after June 30, 2008, whichever comes first."*

"E. coli bacteria shall not exceed a geometric mean of 126 per 100 ml of water for two or more samples taken during any calendar month nor should it exceed 235 counts per 100 ml of water for a single sample maximum value. No single sample maximum for E. coli shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater. Values shown are based on a log standard deviation of 0.4 in freshwater."

These criteria were adopted because there is a stronger correlation between the concentration of E. coli and the incidence of gastrointestinal illness than with fecal coliform. E. coli are bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

For bacteria TMDL development after January 15, 2003, E. coli has become the primary applicable water quality target. However, the loading rates for watershed-based modeling are available only in terms of fecal coliform. Therefore, during the transition from fecal coliform to E. coli criteria, DCR, DEQ and EPA have agreed to apply a translator to in-stream fecal coliform data to determine whether reductions applied to the fecal coliform load would result in meeting in-stream E. coli criteria. The fecal coliform model and in-stream translator are used to calculate E. coli TMDLs. The following regression based in-stream translator is used to calculate E. coli concentrations from fecal coliform concentrations.

$$\textit{E. coli concentration (cfu/100 ml)} = 2^{-0.0172} \times \textit{(FC concentration (cfu/100ml))}^{0.91905}$$

For Falling River, the TMDL is required to meet both the geometric mean and instantaneous criterion. The modeled daily fecal coliform concentrations are converted to daily E. coli concentrations using the in-stream translator. The TMDL development process also must account for seasonal and annual variations in precipitation, flow, land use, and pollutant contributions. Such an approach ensures that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect fecal coliform loading.

2.0 TMDL Endpoint Identification

2.1 Selection of TMDL Endpoint and Water Quality Targets

Three segments on Falling River, located within Campbell and Appomattox Counties of Virginia, were initially placed on the 1998 303(d) list for violations of the fecal coliform standards for contact recreation uses. These three segments, along with a fourth segment, were also included on the 2002 303(d) list. The impaired segments comprise approximately 10.5 miles of Falling River.

One of the first steps in developing TMDLs is determining the numeric endpoints, or water quality goals/targets, for each waterbody. Water quality targets compare the current stream conditions to the expected restored stream conditions after TMDL load reductions are implemented. Numeric endpoints for the Falling River TMDL are established in the Virginia Water Quality Standards (9 VAC 25-260-20), which states that all waters in the state should be free from any substances that can cause the water to violate the state numeric standards, interfere with its designated uses, or adversely affect human health and aquatic life. Therefore the current water quality target for Falling River, as stated in 9 VAC 25-260-170.A and 9 VAC 25-260-170.B (Chapter 1), is an E. coli count where the geometric mean is not greater than 126 counts per 100 ml for two or more water quality samples taken during any calendar month, and does not exceed 235 counts per 100 ml at any time.

2.2 The Critical Condition

The critical condition is considered the “worst case scenario” of environmental conditions in Falling River. If the TMDL is developed such that the water quality targets are met under the critical condition, then the water quality targets would be met under all other conditions.

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of Falling River is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards.

Falling River flows through a predominantly rural setting, with forested and agricultural lands comprising the dominant land uses in the basin. Potential sources of fecal coliform include run-off from livestock grazing, manure applications, industrial processes, and residential waste. The Falling River critical condition will need to consider the location of large outfalls and contributions made from those outfalls during dry conditions, when there is little stream flow to dilute bacteria. If there are no significant dry weather flows (contributions from the outfalls), then the levels of fecal coliform may be attributed to direct deposition from livestock, wildlife, and failed septic systems.

Fecal coliform loadings result from sources that can contribute during wet weather and dry weather. The critical condition of Falling River was determined from the available in-stream water quality data, as well as bacteria source tracking (BST) data collected by DEQ from December 2002 to November 2003, and flow data obtained from USGS gauging station # 02064000, located on the mainstem of Falling River. Due to the recent adoption of E. coli as the indicator species for bacteria, bacteria data were expressed as E. coli and not as fecal coliform; as previously stated, for this TMDL fecal coliform concentrations were modeled and then translated to E. coli concentrations. Plotting bacteria water quality data along with stream flow data revealed that the largest violations were occurring predominantly during low flow conditions. Figure 2-1 depicts E. coli concentrations at the three water quality stations (4-AFRV002.78, 4-AFRV017.71, 4-AMEY016.00) in the watershed with the most existing data, plotted with USGS stream flow data. The data presented were collected from January 2000 to October 2003.

Bacteria source tracking data were also plotted to examine seasonal trends related to hydrologic conditions. Similarly, BST data showed that the highest E. coli concentrations were observed during low flow periods. The highest observed E. coli concentration across sites occurred at station 4-AFRV002.78 during a low flow summer period. Figure 2-2 depicts E. coli concentrations at the 3 BST monitoring stations, plotted with USGS stream flow data.

Low flow periods were considered in the critical condition because many of the observed violations occurred under these conditions. Violations under these conditions would occur from direct sources of bacteria, and would most likely violate the geometric mean standard. However, this TMDL is required to meet both the geometric mean and instantaneous bacteria standards. Violations of the instantaneous standard would occur in wet weather, high flow conditions, when large amounts of bacteria can enter the stream from indirect non-point sources. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions and dry weather, low flow conditions in order to comply with both the instantaneous and geometric mean bacteria standards.

2.3 Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality as a result of hydrologic and climatological patterns. Seasonal variations were explicitly included in the modeling approach for this TMDL. The continuous simulation model developed for this TMDL explicitly incorporates the seasonal variations of rainfall, runoff and fecal coliform wash-off by using an hourly time-step. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. This allowed the consideration of temporal variability in fecal coliform loading within the watershed.

Figure 2-1: Flow and E. coli Concentrations at Water Quality Monitoring Stations

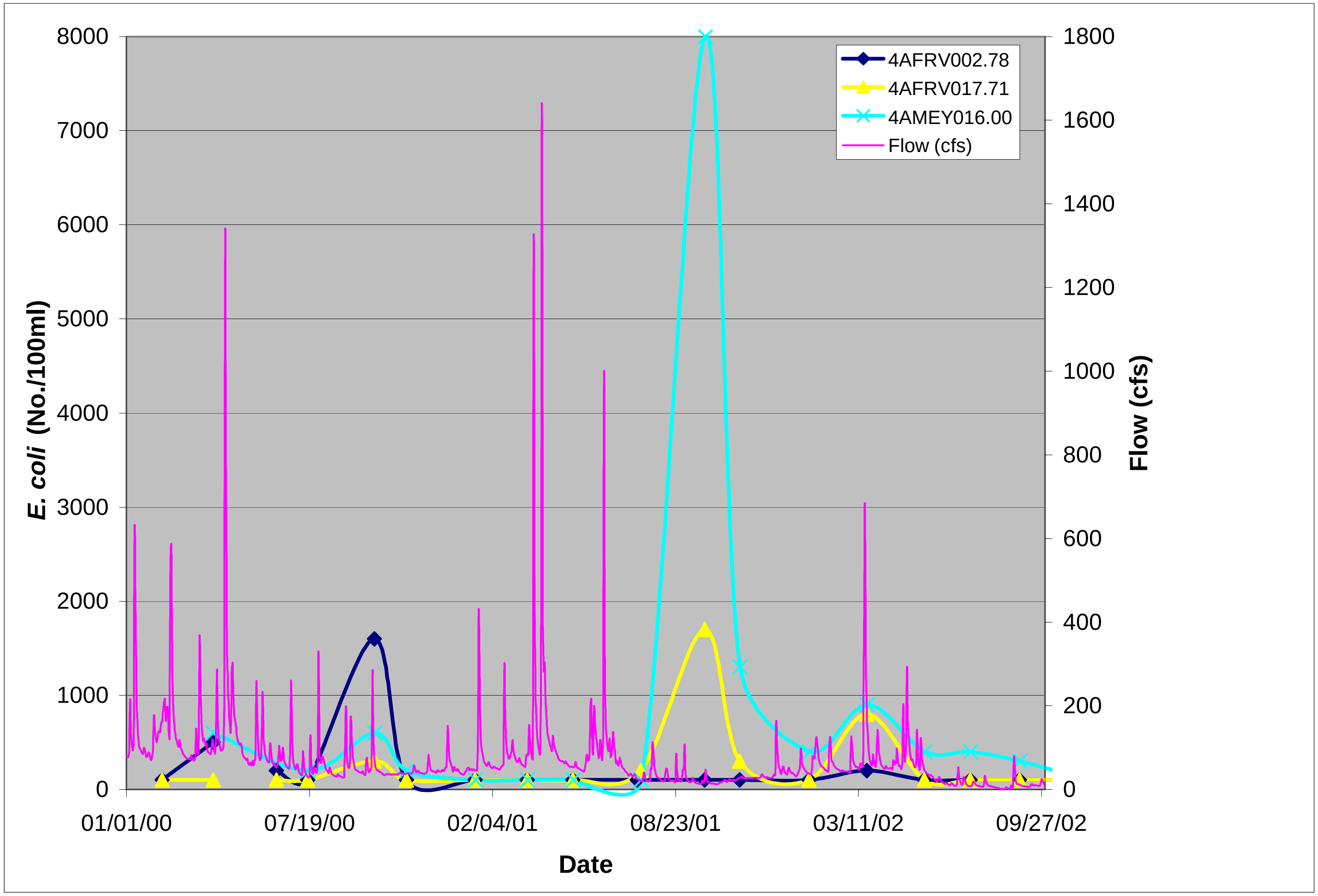
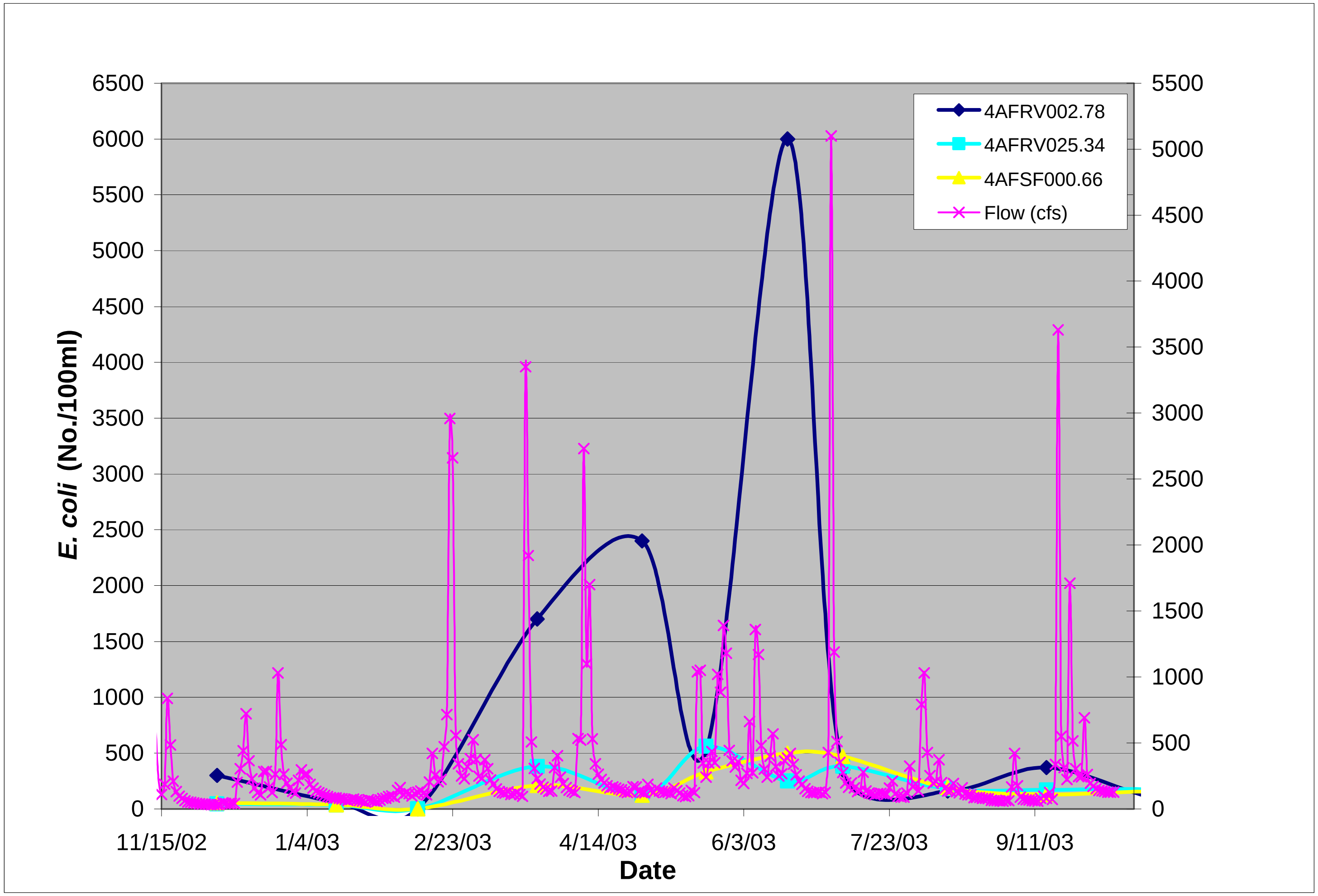


Figure 2-2: Flow and E. coli Concentrations from Bacteria Source Tracking Conducted at Water Quality Monitoring Stations



3.0 Watershed Description and Sources Assessment

In this section, the types of data available and information collected for the development of the Falling River TMDL are presented. This information was used to characterize Falling River and its watershed and to inventory and characterize the potential point and non-point sources of fecal coliform in the watershed.

3.1 Data and Information Inventory

A wide range of data and information were used in the development of this TMDL. Categories of data that were used include the following:

(1) Physiographic data that describe physical conditions (i.e., topography, soils, and land use) within the watershed

(2) Hydrographic data that describe physical conditions within the stream, such as the stream reach network and connectivity, and the stream channel depth, width, slope, and elevation

(3) Data related to uses of the watershed and other activities in the basin that can be used in the identification of potential fecal coliform sources

(4) Environmental monitoring data that describe stream flow and water quality conditions in the stream

Table 3-1 shows the various data types and the data sources used in the Falling River TMDL.

Table 3-1: Inventory of Data and Information Used in the Falling River TMDL Development

Data Category	Description	Potential Source(s)
Watershed physiographic data	Watershed boundary	USGS, DEQ
	Land use/land cover	NLCD
	Soil data (SSURGO, STATSGO)	NRCS, BASINS
	Topographic data (USGS-30 meter DEM, USGS Quads)	USGS, DCR
Hydrographic data	Stream network and reaches (RF3)	BASINS, NHD, Field surveys
	Stream morphology	
Weather data	Hourly meteorological conditions	NCDC, Earth Info
Watershed activities/ uses data and information related to fecal coliform production	Information, data, reports, and maps that can be used to support fecal coliform source identification and loading	State, county, and city governments, local groups and stakeholders
	Livestock inventory, grazing, stream access, and manure management	DCR, Robert E. Lee SWCD, NRCS
	Wildlife inventory	DGIF
	Septic systems inventory and failure rates	Campbell and Appomattox Department of Health, Campbell County Utility Service Authority, U.S. Census Bureau
	Straight pipes	DEQ
	Best management practices (BMPs)	DCR, NRCS, Robert E. Lee SWCD
Point sources and direct discharge data and information	Permitted facilities locations and discharge monitoring reports (DMR)	EPA Permit Compliance System (PCS), VPDES, DEQ
Environmental monitoring data	Ambient in-stream monitoring data	DEQ
	Stream flow data	USGS, DEQ

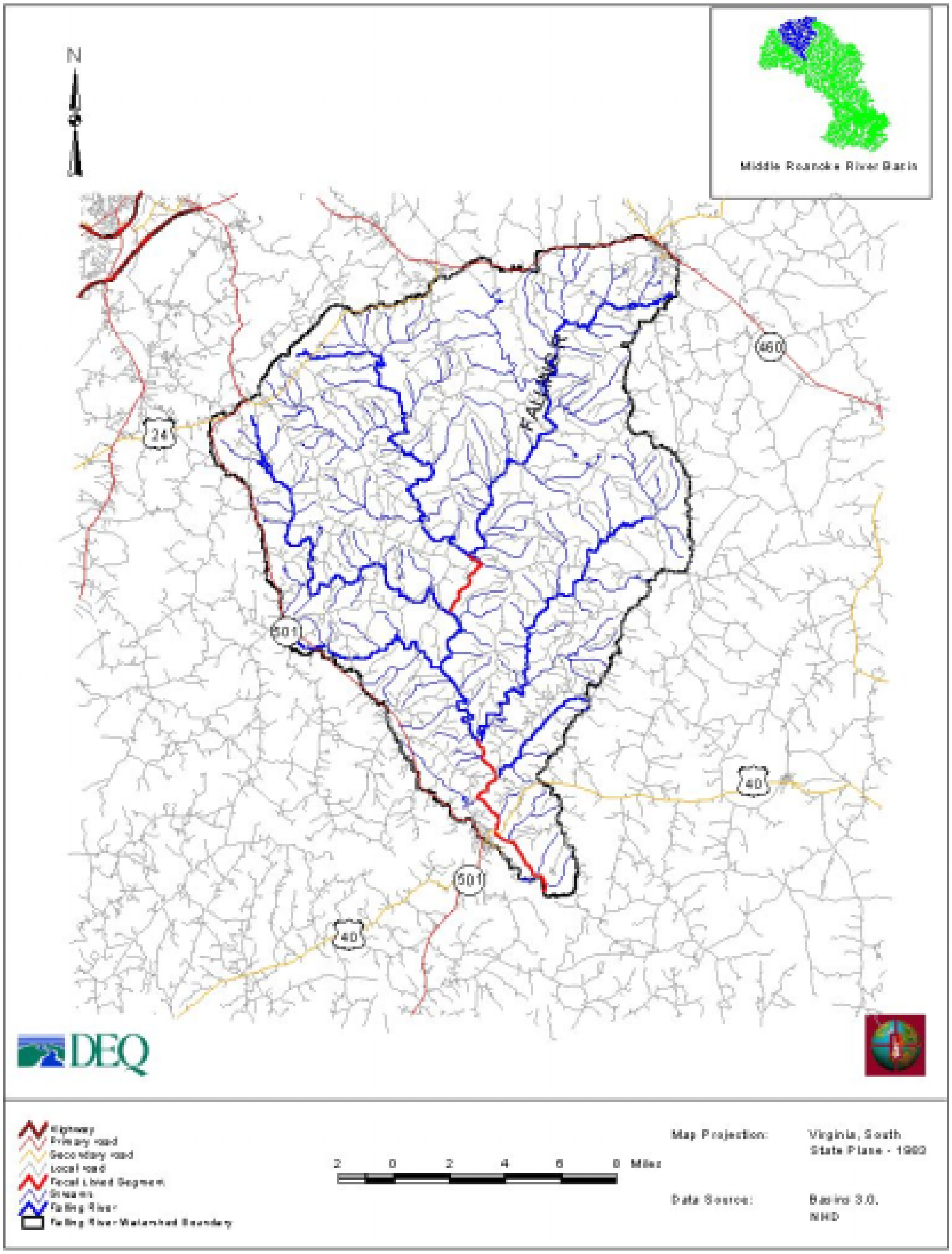
Notes
DCR: Virginia Department of Conservation and Recreation
DEQ: Virginia Department of Environmental Quality
DGIF: Virginia Department of Game and Inland Fisheries
EPA: Environmental Protection Agency
NCDC: National Climatic Data Center
NHD: National Hydrography Dataset
NLCD: National Land Coverage Data
NRCS: Natural Resources Conservation Service
SWCD: Soil and Water Conservation District
USGS: U.S. Geological Survey
VPDES: Virginia Pollutant Discharge Elimination System

3.2 Watershed Description and Identification

3.2.1 Watershed Boundaries

Falling River is a tributary of the Middle Roanoke River Basin. The Falling River watershed is approximately 151,150 acres, or 236 square miles. The watershed is located within Campbell and Appomattox Counties of Virginia. Approximately 75 percent of the drainage basin is located in Campbell County; the remainder of the watershed is located in Appomattox County. The watershed makes up about 35 percent of the land area in Campbell County, and 16 percent of the land area in Appomattox County. State Highway 501 (SH-501) runs along the western boundary of the watershed in a north to south direction. U.S. Highway 40 (US-40) passes through the lower section of the watershed in an east to west direction. U.S. Highway 24 (US-24) runs along the northern boundary of the watershed in a west to northeast direction. State Highway 460 (SH-460) goes along a portion of the northern boundary of the watershed in an east to north direction. Figure 3-1 is a map showing the location and the boundary of the watershed.

Figure 3-1: Location and Boundary of Falling River Watershed



3.2.2 Topography

A digital elevation model (DEM) and USGS 7.5 minute quadrangle maps were used to characterize topography in the watershed. DEM data was obtained from BASINS, and compared to the Campbell and Appomattox, Virginia USGS 7.5 minute quadrangle maps. Elevation in the watershed ranged from 332 to 1,437 feet above mean sea level.

3.2.3 Soils

The Falling River watershed soil characterization was based on data obtained from BASINS. There are seven general soil associations located in the Falling River watershed (see Table 3-2). The two dominant soil types in the watershed are the Cecil-Madison-Enon and Georgeville-Mason-Lignum soil associations. Cecil-Madison-Enon soils are fine, well-drained mineral soils derived from felsic parent materials. Georgeville-Nason-Lignum soils are gently sloping to steep, very deep, well-drained, moderately permeable soils formed in material weathered from fine-grained rocks of the Carolina Slate Belt. The distribution of soils in the Falling River watershed is presented in Table 3-2.

Table 3-2: Soil Types and Characteristics in the Falling River Watershed

Map Unit ID	Soil Association	Percent	Hydrologic Soil Group
VA014	NASON-MANTEO-GOLDSTON	8.3	C/D
VA019	CECIL-MADISON-ENON	26.8	B/C
VA029	IREDELL-POINDEXTER-PACOLET	0.7	C/D/B
VA030	APPLING-WEDOWEE-LOUISBURG	13.2	B
VA031	CULLEN-WILKES-IREDELL	15.7	C
VA042	MAYODAN-CREEDMOOR-PINKSTON	7.6	B/C
VA045	GEORGEVILLE-NASON-LIGNUM	27.7	B

Source: NRCS

The hydrologic soil group linked with each soil association is also presented in Table 3-2. The hydrologic soil groups represent different levels of infiltration capacity of the soils. Hydrologic soil group "A" designates soils that are well to excessively well drained, whereas hydrologic soil group "D" designates soils that are poorly drained. This means that soils in hydrologic group "A" allow a larger portion of the rainfall to infiltrate and become part of the ground water system. On the other hand, compared to the soils in hydrologic group "A", soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate and become part of the ground water. Consequently, more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in Table 3-3.

Table 3-3: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover

3.2.4 Land Use

Land use characterization was based on National Land Cover Data (NLCD) developed by USGS. The distribution of land uses in Falling River, by land area and percentage, is presented in Table 3-4. Dominant land uses in the watershed are forested land (67%) and agricultural land (28%), which account for a combined 95% of the land area in the Falling River watershed. Brief descriptions of land use classifications are presented in Table 3-5.

Table 3-4: Land Use Distribution in the Falling River Watershed

Land Use Category	NLCD Land Use Type	Acres	Percent of Watershed's Land Area
Water/Wetlands	Open Water	832.5	0.6
	Woody Wetlands	998.4	0.7
	Emergent Herbaceous Wetlands	148.9	0.1
Urban	Low Intensity Residential	1246.1	0.8
	High Intensity Residential	2.4	0.0
	Commercial/Industrial/Transportation	260.5	0.2
Agriculture	Pasture/Hay	38377.4	25.4
	Row Crop	4337.0	2.9
Forest	Deciduous Forest	61591.7	40.7
	Evergreen Forest	17524.8	11.6
	Mixed Forest	22411.4	14.8
Other	Transitional	3464.6	2.3
Total		**151,196**	**100**

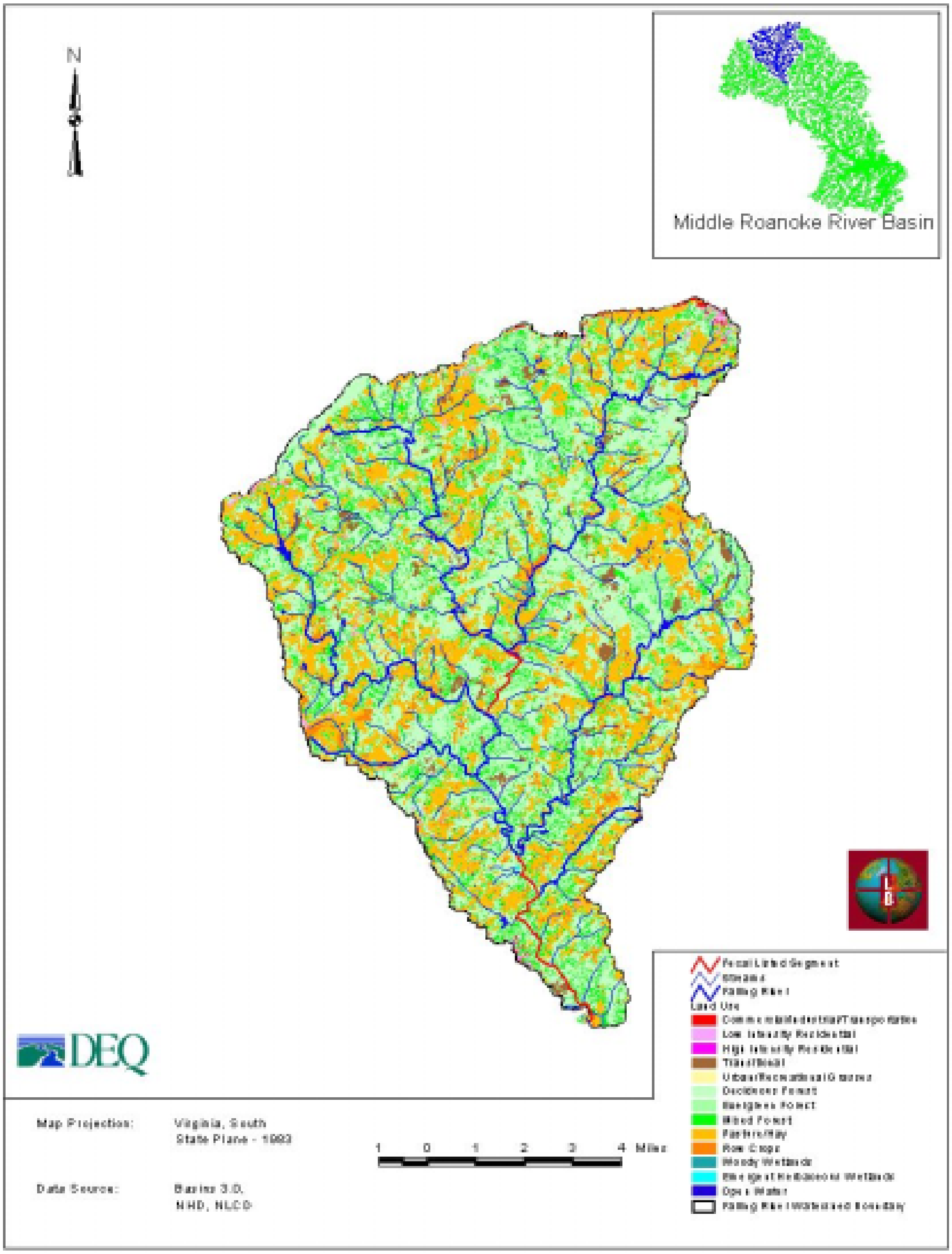
Table 3-5: Descriptions of Land Use Types

Land Use Type	Description
Open Water	Areas of open water, generally with less than 25 percent or greater cover of water
Woody Wetlands	Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Low Intensity Residential	Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.
High Intensity Residential	Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80-100 percent of the cover.
Commercial/Industrial/Transportation	Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as High Intensity Residential.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Row Crop	Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.
Deciduous Forest	Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas characterized by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
Quarries/Strip Mines/Gravel Pits	Areas of extractive mining activities with significant surface expression.
Transitional	Areas of sparse vegetative cover (less than 25 percent that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.)
Urban/Recreational Grasses	Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Source: NLCD

Figure 3-2 depicts the land use distribution within the Falling River watershed. Forested and agricultural lands are evenly dispersed throughout the watershed. Some urban and residential areas are present in the northernmost part of the watershed.

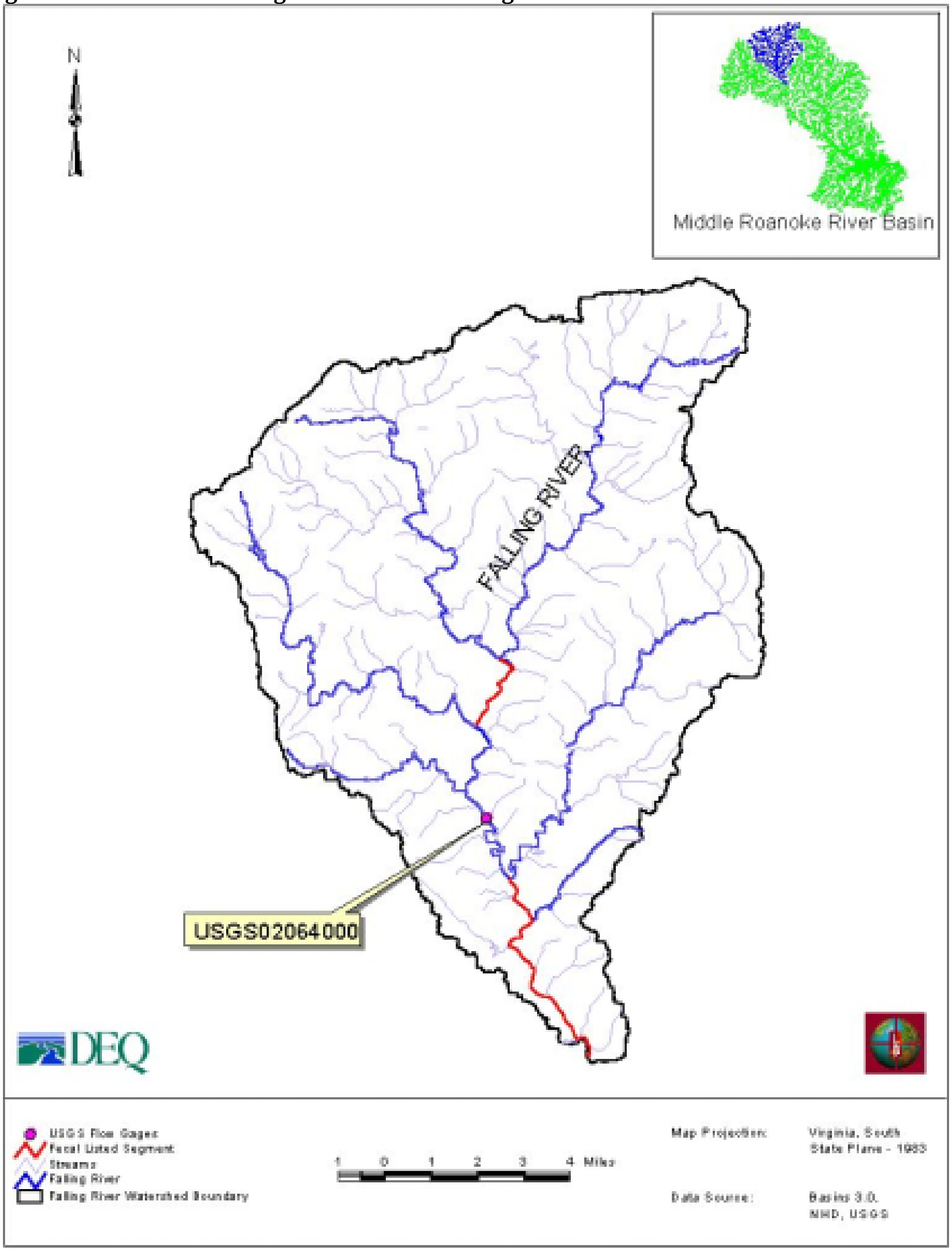
Figure 3-2: Land Use in the Falling River Watershed



3.3 Stream Flow Data

Stream flow data for Falling River was retrieved from USGS stream flow monitoring station ID #2064000 for the period of 1929 to 2003. This monitoring station is located on the mainstem Falling River near Naruna, Virginia (see Figure 3-3). Stream flow data obtained from this station was used in the set-up, hydrological calibration, and validation of the model.

Figure 3-3: Flow Monitoring Station in the Falling River Watershed



3.4 In-Stream Water Quality Conditions

Water quality data for the Falling River watershed was obtained from DEQ, which conducted sampling at 7 water quality monitoring stations located within the boundary of the Falling River watershed. Locations of these stations are summarized in Table 3-6. Stations 1 through 5 are located on the mainstem of Falling River, station 6 is located on Phelps Creek at the Brookneal STP, and station 7 is located on Mollys Creek, a tributary of Falling River. Figure 3-4 depicts the locations of these monitoring stations.

Table 3-6: In-Stream Water Quality Monitoring Stations Located in the Falling River Watershed

No.	Station Id	Station Location	Stream Name	River Mile
1	4-AFRV002.78	Off Route 600 below Brookneal STP	Falling River	2.78
2	4-AFRV010.99	Narana Gage, Route 643	Falling River	10.99
3	4-AFRV017.71	Route 615 Bridge - Campbell County	Falling River	17.71
4	4-AFRV025.34	Falling River at Route 650 Bridge	Falling River	25.34
5	4-AFRV029.24	Falling River at Route 647 bridge	Falling River	29.24
6	4-APLP000.40-TL 4-APLP000.40-BL	Brookneal STP, at dam and 500 yards above dam	Phelps Creek	0.40
7	4-AMEY016.00	Private road off Route 655, below Rustburg	Mollys Creek	16.00

Water quality data collected at station 4-AFRV025.34 were not available. For the other stations, Table 3-7 lists the water quality sampling period of record, the number of samples collected, the minimum and the maximum concentrations observed, and the percentage of samples violating the water quality standard. For in-stream monitoring stations located on the mainstem of Falling River, water quality data collected from stations with multiple samples indicate that violation of the fecal coliform standard ranged from 15 to 60 percent.

Figure 3-4: Falling River Watershed Water Quality Monitoring Stations

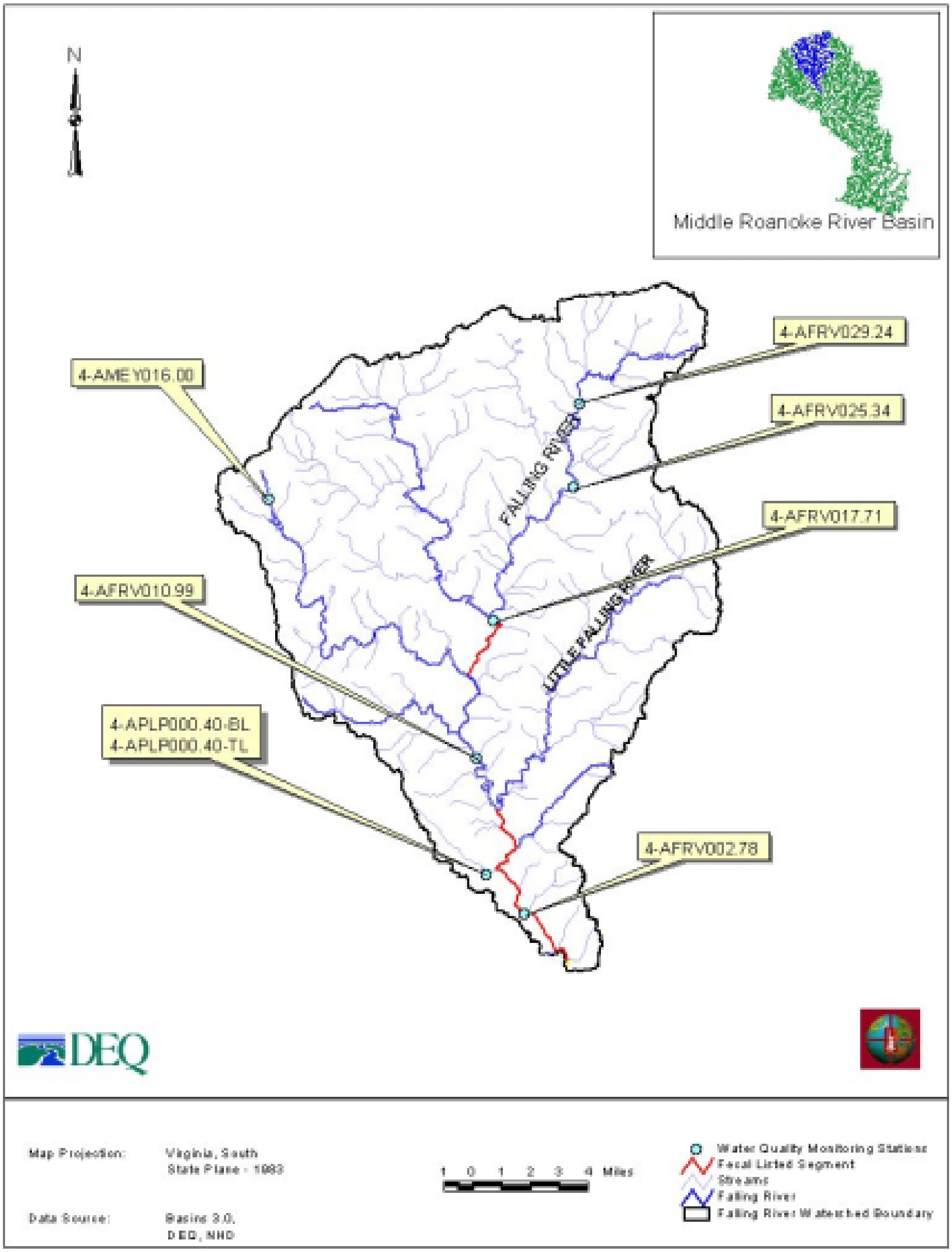


Table 3-7: Summary of Water Quality Sampling Events in the Falling River Watershed

No.	Station Id	Period of Record	Number of Samples	Minimum (cfu/100ml)	Maximum[1] (cfu/100ml)	Violation[2] (%)
1	4-AFRV002.78	1993-2003	46	100	8,000	15
2	4-AFRV010.99	2001-2003	20	50	1,900	40
3	4-AFRV017.71	1993-2003	55	50	8,000	16
4	4-AFRV029.24	2002-2003	10	50	1,500	60
5	4-APLP000.40	2001-2003	15	0	1,816	75
6	4-AMEY016.00	1993-2003	55	100	8,000	22

1: Samples were censured at 8,000 cfu/100ml.
2: The percent violation for geometric mean standard applies to samples collected during any calendar month. The instantaneous standard was used when the sampling frequency was more than 30 days.

3.4.1 Bacteria Source Tracking

As part of the TMDL development, Bacteria Source Tracking (BST) sampling was conducted at three locations on Falling River. The objective of BST was to identify the sources of fecal coliform in the listed segments of Falling River. After identifying these sources, this information was used in the model set-up, and in the distribution of fecal coliform loading among the various sources.

There are various methodologies used to perform BST, which fall into three major categories: molecular, biochemical and chemical. Molecular (genotype) methods are referred to as "DNA fingerprinting", and are based on the unique genetic makeup of different strains, or subspecies, of fecal bacteria. Biochemical (phenotype) methods are based on detecting biochemical substances produced by organisms. The type and quantity of these substances are measured to identify the bacteria source. Chemical methods are based on testing for chemical compounds that are associated with human wastewaters, and are restricted to determining if sources of pollution are human or non-human.

For the Falling River TMDL, the Antibiotic Resistance Analysis (ARA) method of BST was used. ARA has been the most widely used and published BST method to date and has been employed in Virginia, Florida, Kansas, Oregon, South Carolina, Tennessee, and Texas. Advantages of ARA include low cost per sample, and fast turnaround times for analyzing samples. The method can also be performed on large numbers of isolates; typically, 48 isolates per unknown source such as an in-stream water quality sample.

In the Falling River watershed, BST was conducted monthly at three monitoring stations from December 2002 through November 2003. One station was located at the intersection of Falling River and the Route 650 Bridge (4-AFRV025.34), another at the river below the Brookneal STP (4-AFRV002.78), and the third on South Fork Falling River, at the Route 648 Bridge (4-AFSF000.66). A total of 12 sampling events were collected at each station. Figure 3-5 depicts the locations of the monitoring stations in the Falling River watershed.

Four categories of fecal bacteria sources were considered: human, wildlife, livestock, and pet. BST samples collected on February 11, 2003 were below detection limits at all three stations. Results for the remaining 11 sampling events at each station are presented in Table 3-8. E. coli concentrations at BST station 4AFRV002.78, located on the mainstem of Falling River near the mouth, violated the instantaneous E. coli bacteria criteria of 235 cfu/100mL 7 times in the 12 sampling events. In terms of percentages, the instantaneous E. coli standard was violated in 58% of the observed samples. The data indicate that E-coli from human, wildlife, livestock, and pet sources were present in Falling River. The human signature in samples ranged from 0 to 25 percent, the wildlife signature ranged from 0 to 56 percent, the livestock signature ranged from 12 to 100 percent, and the pet signature ranged from 0 to 54 percent.

Figure 3-5: Falling River Watershed Bacteria Source Tracking Sampling Stations

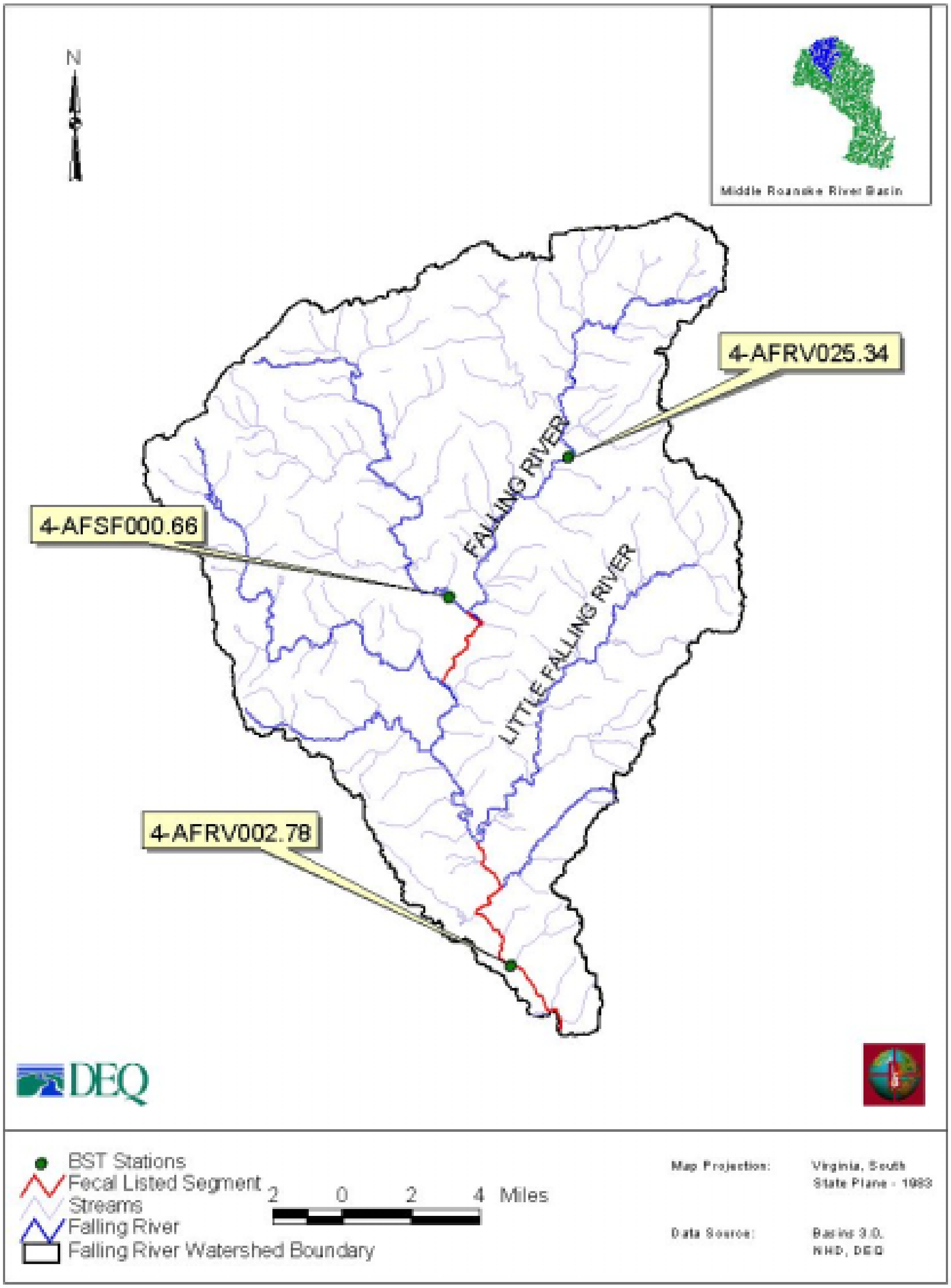


Table 3-8: Results of BST Analysis Conducted in the Falling River Watershed

Location	Date	E-Coli MFM-FCBR/100ml	Percent of Enterococci Classified as			
			Wildlife	Human	Livestock	Pet
4AFRV002.78	12/04/02	300	0%	0%	100%	0%
	1/14/2003	63	17%	0%	70%	13%
	3/24/2003	1700	4%	17%	50%	29%
	4/29/2003	2400	13%	0%	33%	54%
	5/21/2003	530	50%	0%	46%	4%
	6/18/2003	6000	0%	17%	29%	54%
	7/7/2003	350	50%	0%	29%	21%
	8/12/2003	160	19%	0%	81%	0%
	9/15/2003	370	25%	0%	63%	12%
	10/22/2003	100	38%	0%	12%	50%
	11/17/2003	98	33%	0%	46%	21%
4AFRV025.34	12/04/02	46	4%	0%	96%	0%
	1/14/2003	34	38%	0%	24%	38%
	3/24/2003	380	8%	25%	59%	8%
	4/29/2003	120	4%	0%	87%	9%
	5/21/2003	560	17%	4%	54%	25%
	6/18/2003	250	33%	0%	29%	38%
	7/7/2003	380	33%	0%	21%	46%
	8/12/2003	180	38%	0%	62%	0%
	9/15/2003	170	0%	0%	100%	0%
	10/22/2003	170	25%	4%	59%	12%
	11/17/2003	80	17%	0%	58%	25%
4AFSF000.66	12/04/02	54	4%	0%	96%	0%
	1/14/2003	38	13%	4%	83%	0%
	3/24/2003	210	13%	13%	66%	8%
	4/29/2003	120	13%	4%	66%	17%
	5/21/2003	330	13%	0%	66%	21%
	6/18/2003	500	17%	4%	41%	38%
	7/7/2003	470	17%	4%	33%	46%
	8/12/2003	190	56%	0%	44%	0%
	9/15/2003	130	0%	0%	100%	0%
	10/22/2003	150	50%	0%	38%	12%
	11/17/2003	34	8%	0%	88%	4%

1: Samples collected on 2/11/03 were below detection limits for all three stations

3.5 Fecal Coliform Sources Assessment

This section focuses on characterizing the sources that potentially contribute to the fecal coliform loading in the Falling River watershed. These sources include permitted facilities, sanitary sewer systems and septic systems, livestock, land application of manure and biosolids, wildlife, and pets. Chapter 4 includes a detailed presentation of how these sources are incorporated and represented in the model.

3.5.1 Permitted Facilities

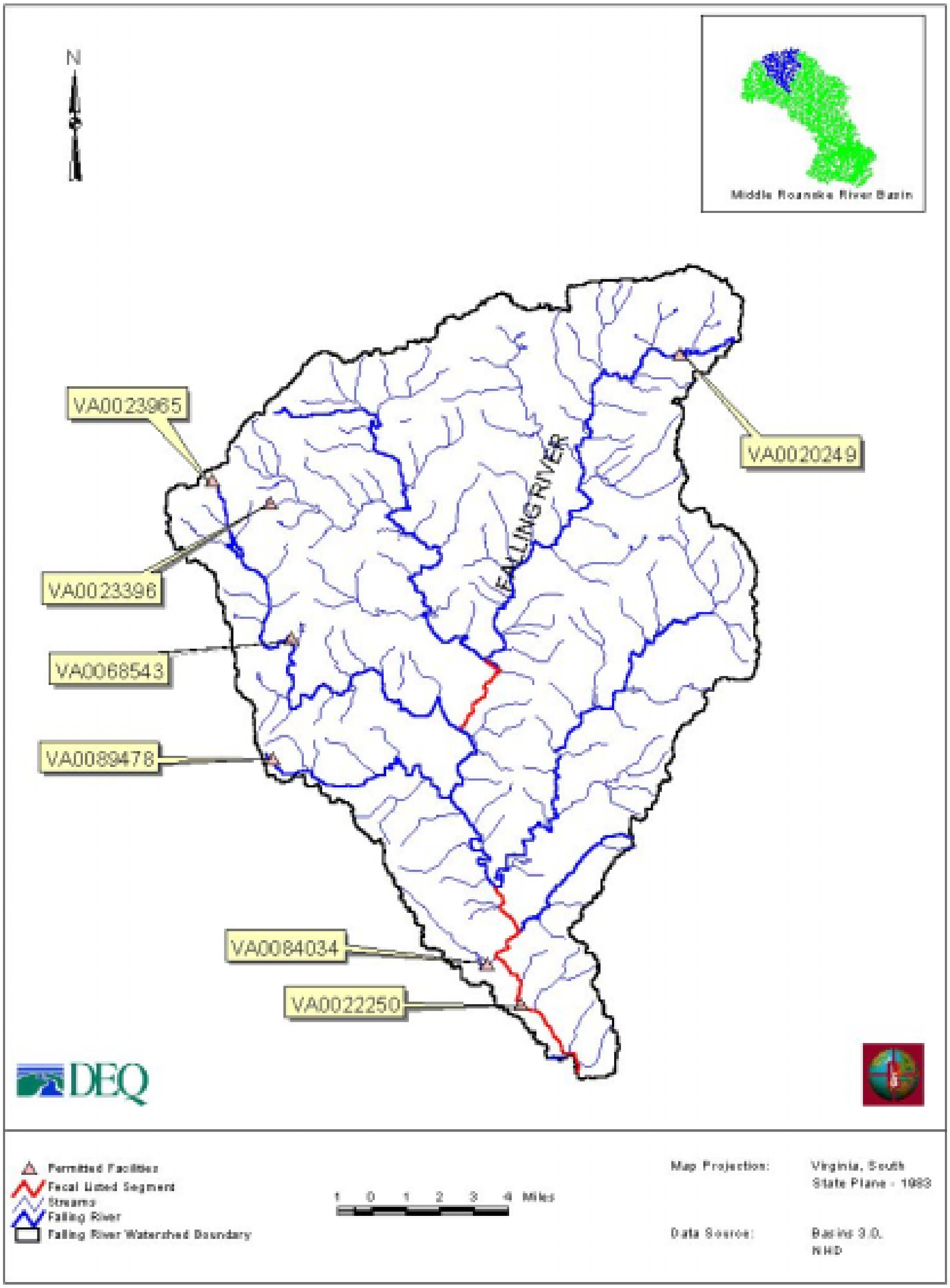
Data obtained from the DEQ's West Central Regional Office indicate that there are 7 permitted facilities located in the Falling River watershed. The permit number, design flow, and status for each treatment plant are presented in Table 3-9. The number of connections to each facility is also presented in Table 3-9. The locations of these facilities are presented in Figure 3-6.

Table 3-9: Permitted Discharges in the Falling River Watershed

Permit Number	Facility Name	Design Flow (gallons per day)	No. of Connections[1]	Status
VA0020249	Appomattox STP	170,000	356	Active
VA0022250	Town of Brookneal - Lagoon	82,000	1259	Active
VA0023396	DOC Rustburg	28,000	0	Active
VA0023965	Rustburg WWTP	200,000	105	Active
VA0068543	Thousand Trails Lynchburg Preserve	39,600	0	Active
VA0084034	Brookneal WTP	41,000	Not Applicable	Active
VA0084034	Brookneal WTP	600	Not Applicable	Active
VA0089478	Gladys Timber Products	200,000	Not Applicable	Active

1: Number of connections is the number of households connected to the corresponding Wastewater treatment facility.

Figure 3-6: Location of Permitted Facilities in the Falling River Watershed



The available flow data for the permitted facilities was retrieved and analyzed. Figure 3-7 to Figure 3-11 show the average and maximum monthly flows for the facilities for which flow data were available. Average flows for the permitted facilities were used in the HSPF model set-up and calibration.

Fecal coliform data were available only for the Thousand Trails Lynchburg Preserve treatment facility (Figure 3-8), and were not available for other permitted facilities. The waste treatment plants use chlorine for disinfection, and measure total residual chloride (TRC) as an indication of fecal coliform levels. Figure 3-12 to Figure 3-17 show TRC contact levels for facilities where data were available. The available data indicate that adequate disinfection was achieved at the plants, and that these facilities were not a large source of fecal coliform loading. For TMDL development, a conservative approach was taken by assuming a concentration of 2 cfu/100 ml was present in the plant effluent. This concentration was used in HSPF model calibration.

Figure 3-7: Appomattox STP Average and Maximum Monthly Flow

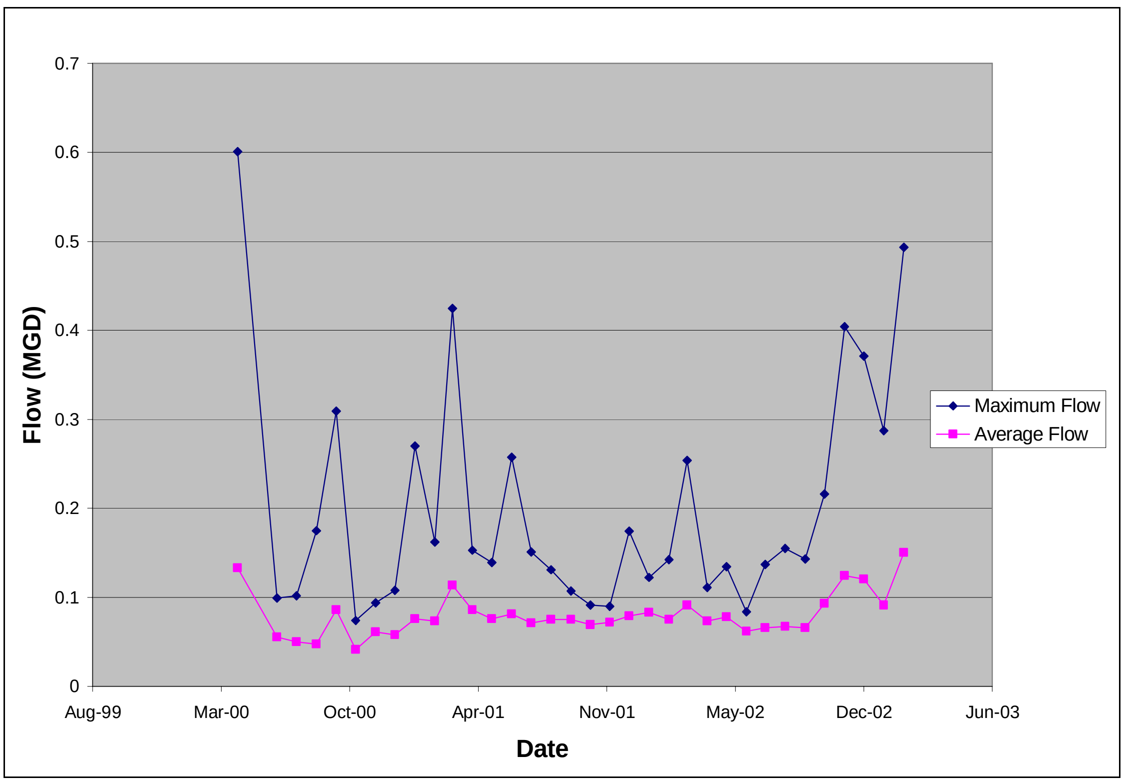


Figure 3-8: Town of Brookneal - Falling River Lagoon Average and Maximum Monthly Flow

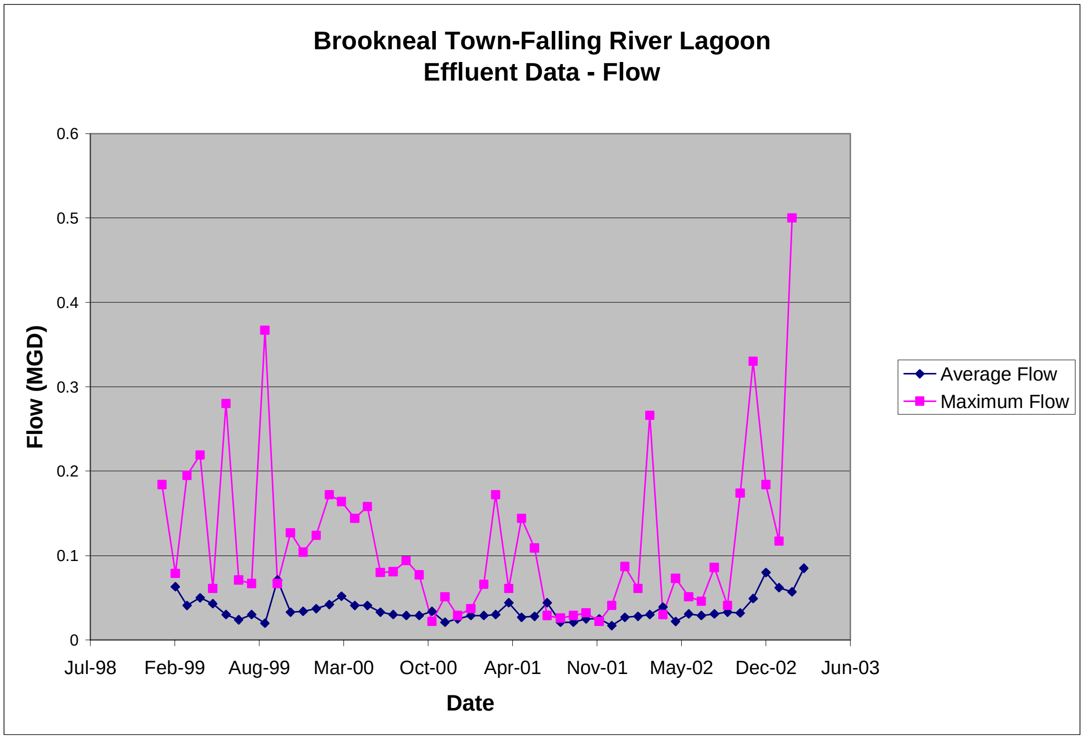


Figure 3-9: DOC Rustburg Average and Maximum Monthly Flow

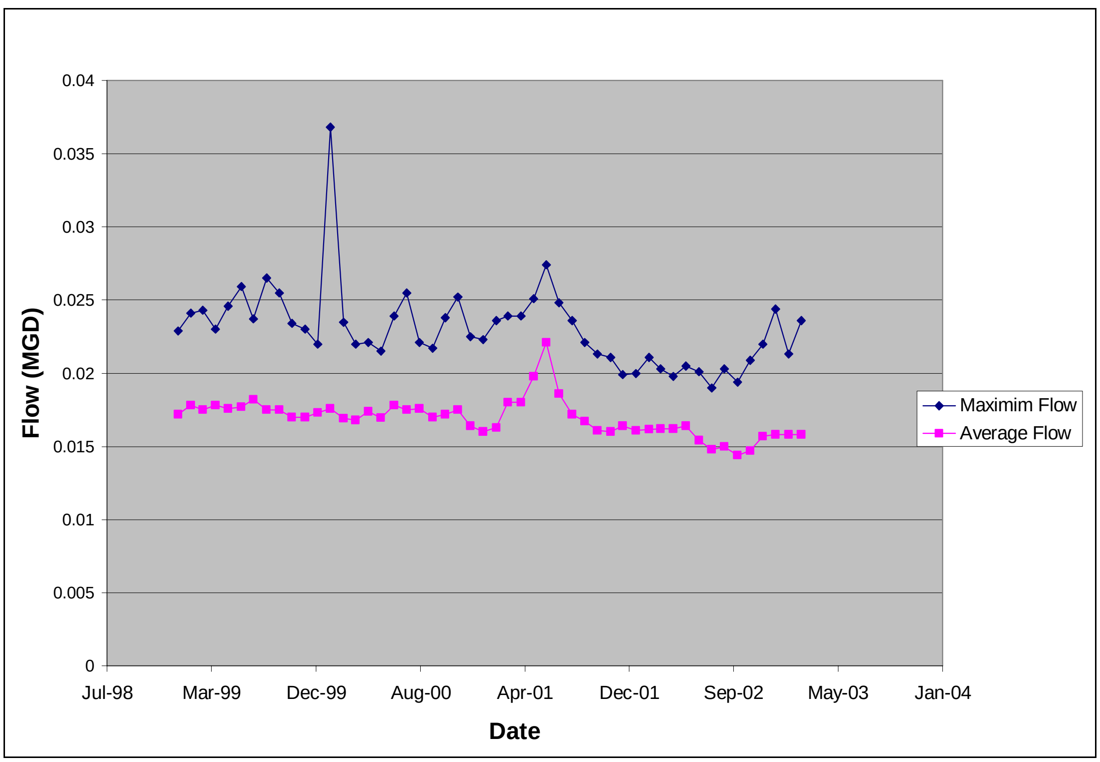


Figure 3-10: Rustburg WWTP Average and Maximum Monthly Flow

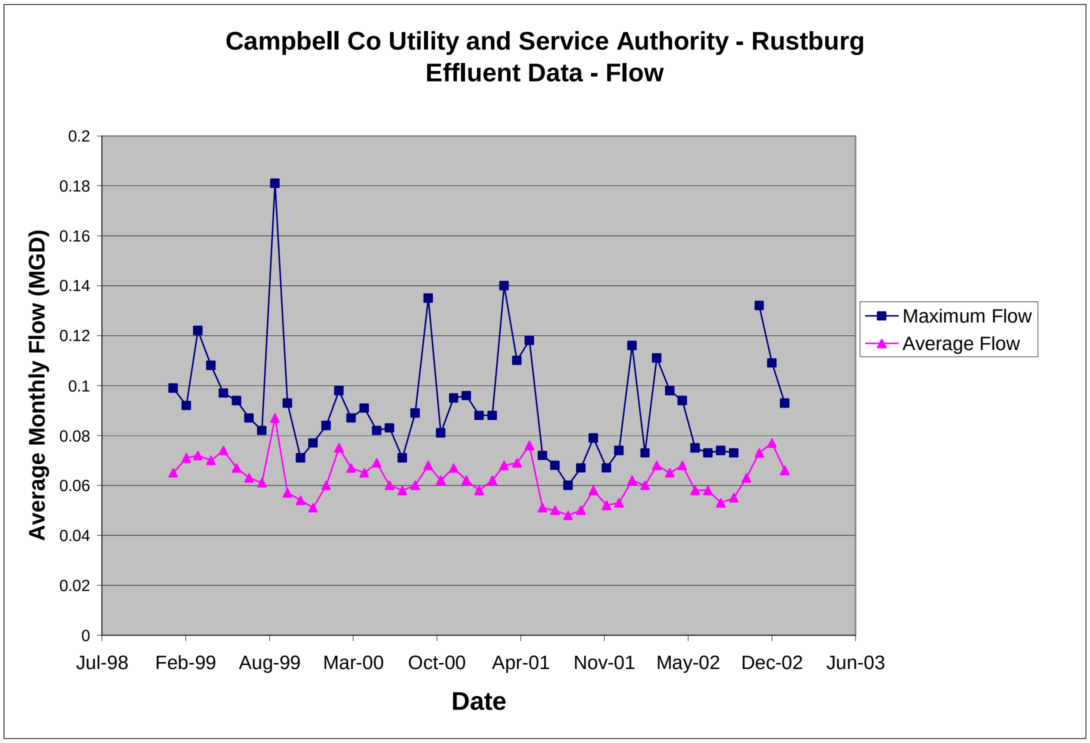


Figure 3-11: Thousand Trails Lynchburg Preserve Average and Maximum Monthly Flow

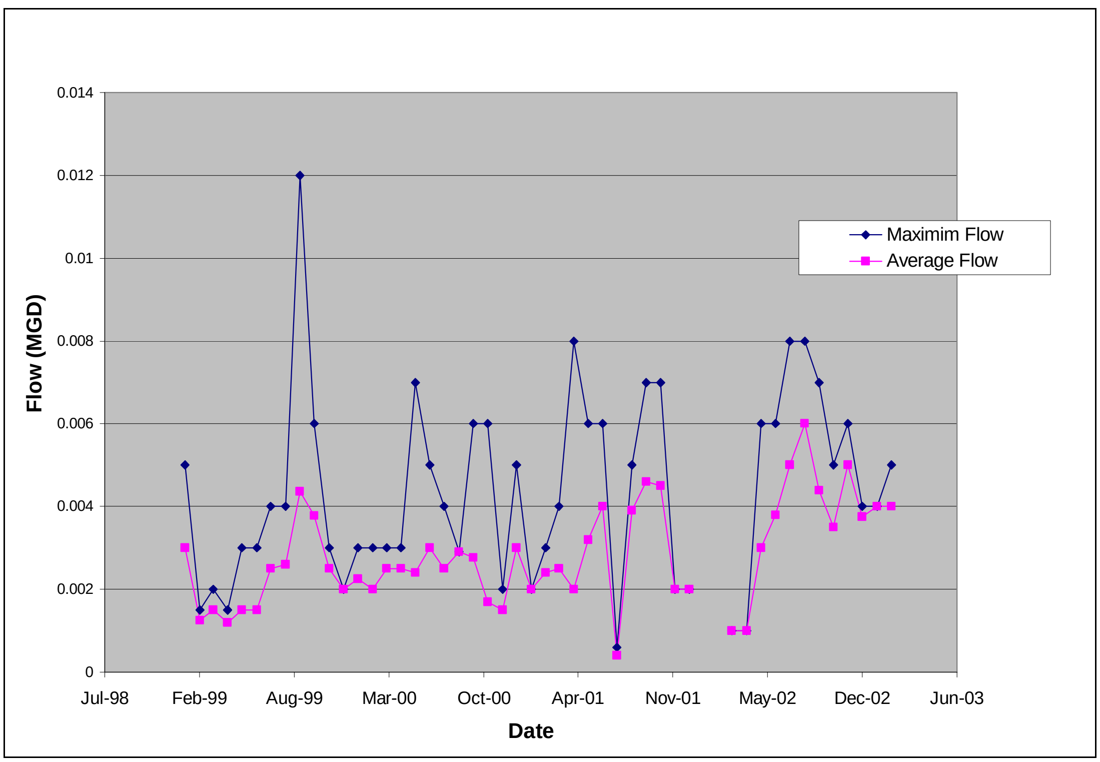


Figure 3-12: Thousand Trails Lynchburg Preserve Fecal Coliform Average Concentration

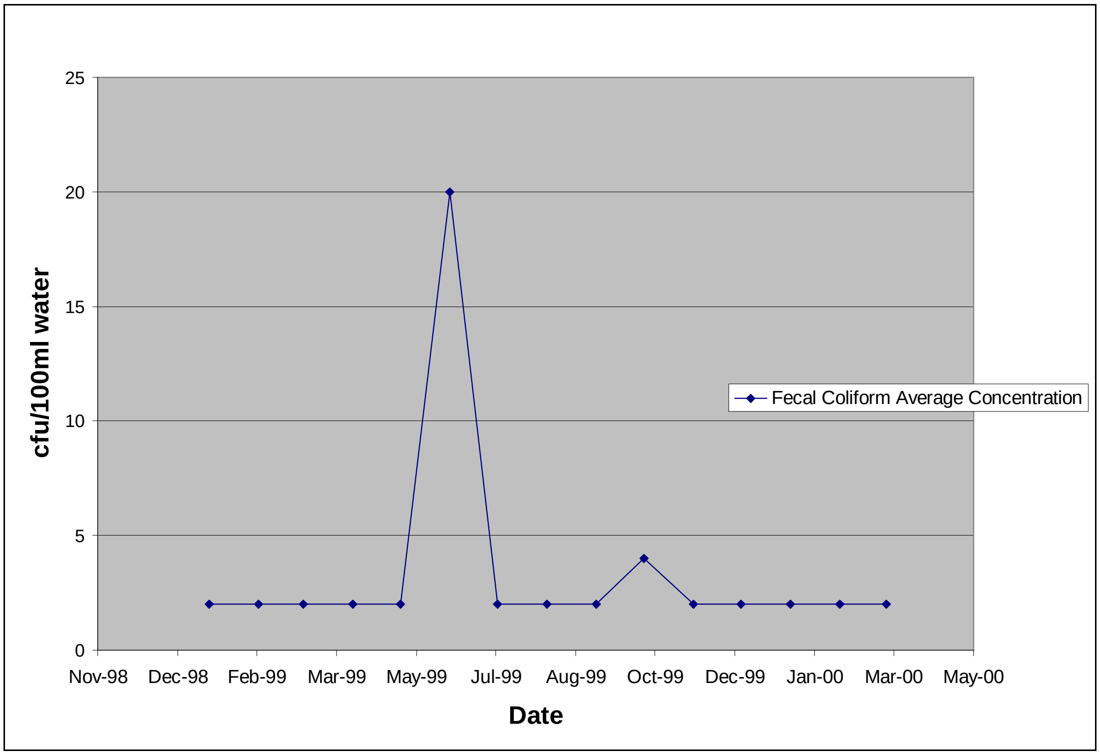


Figure 3-13: Appomattox STP Cl2 Total Contact Minimum Concentration

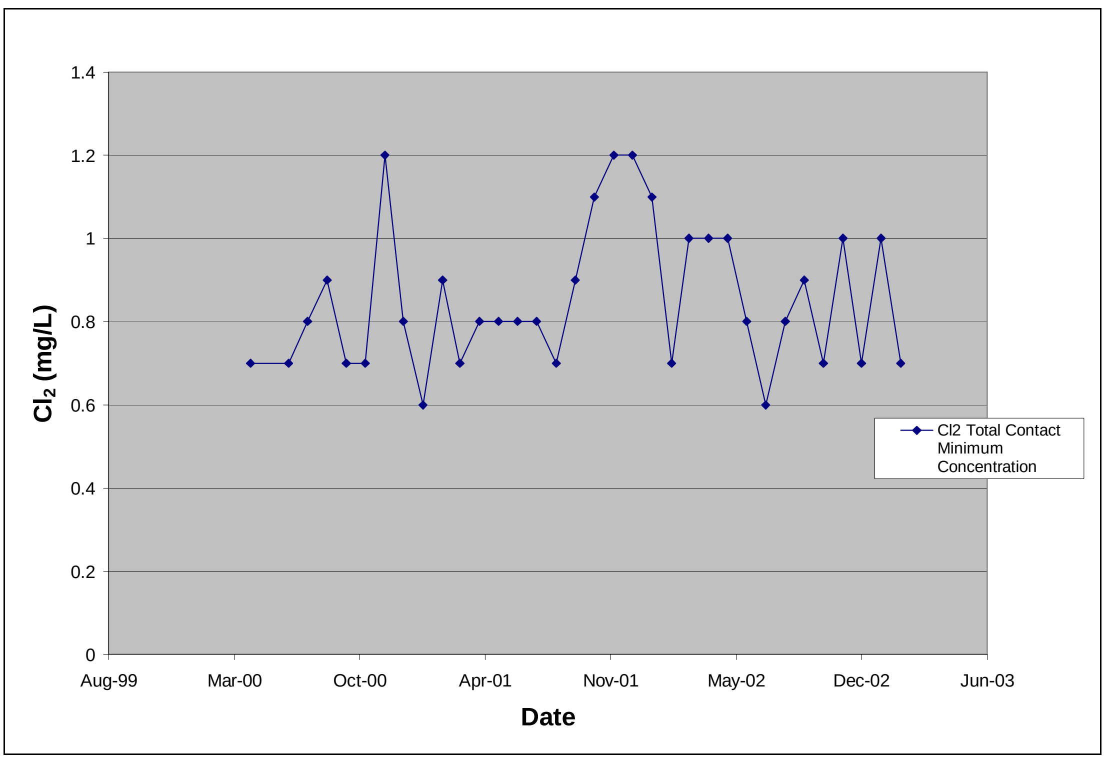


Figure 3-14: Town of Brookneal - Falling River Lagoon Cl2 Total Maximum and Minimum Concentration

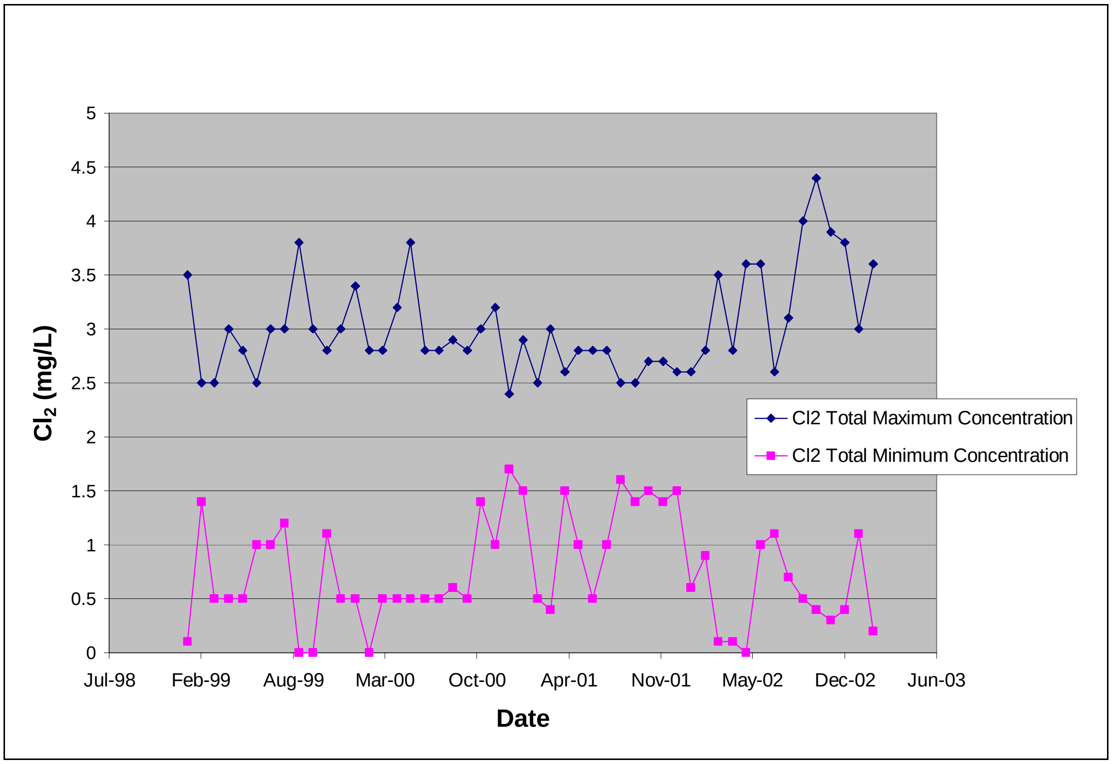


Figure 3-15: DOC Rustburg Cl2 Total Contact Minimum Concentration

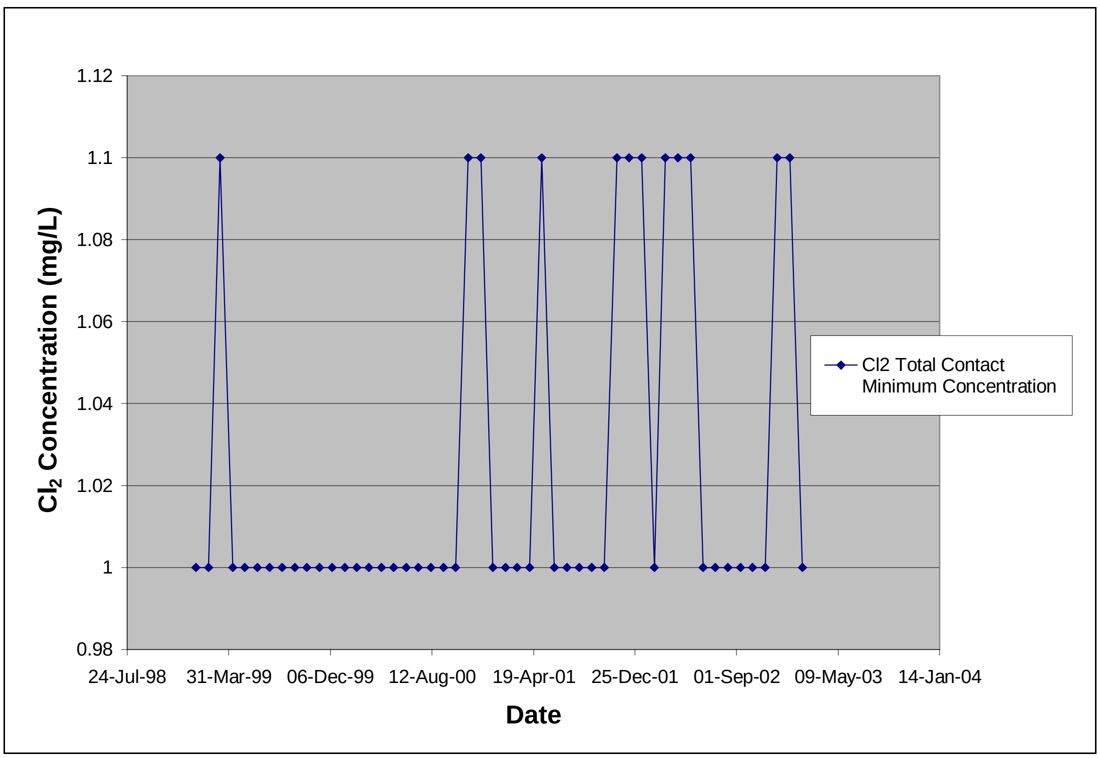


Figure 3-16: Rustburg WWTP Cl2 Total Contact Minimum Concentration

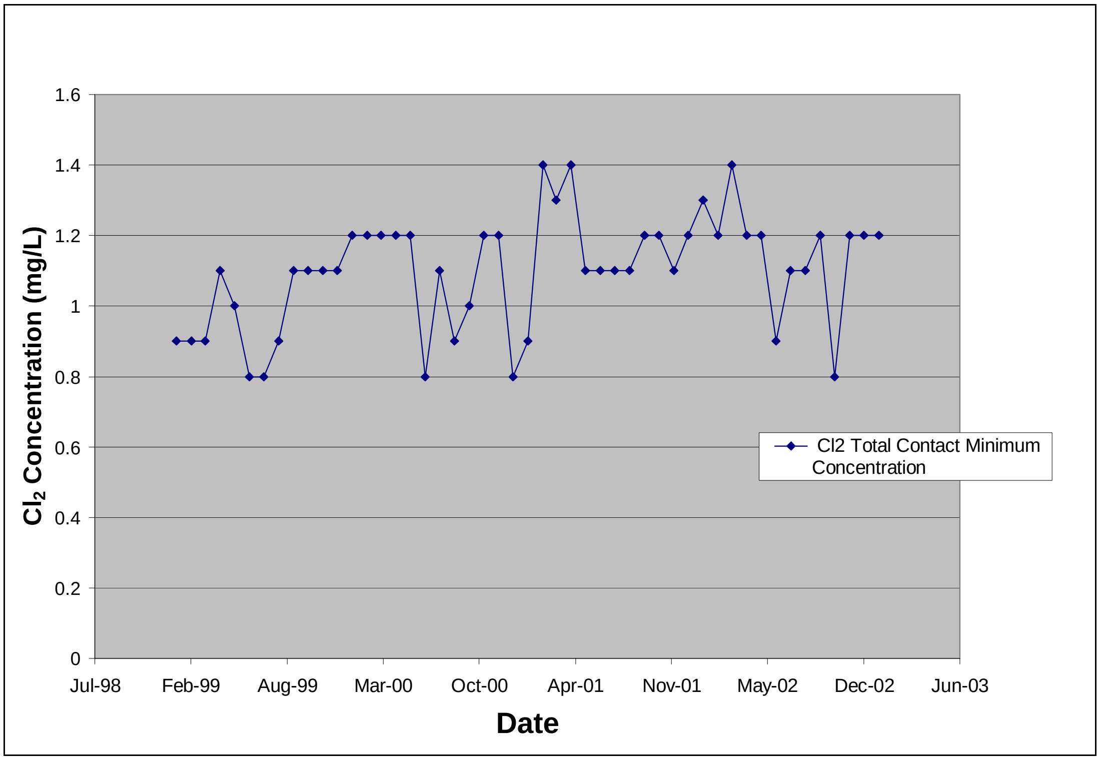
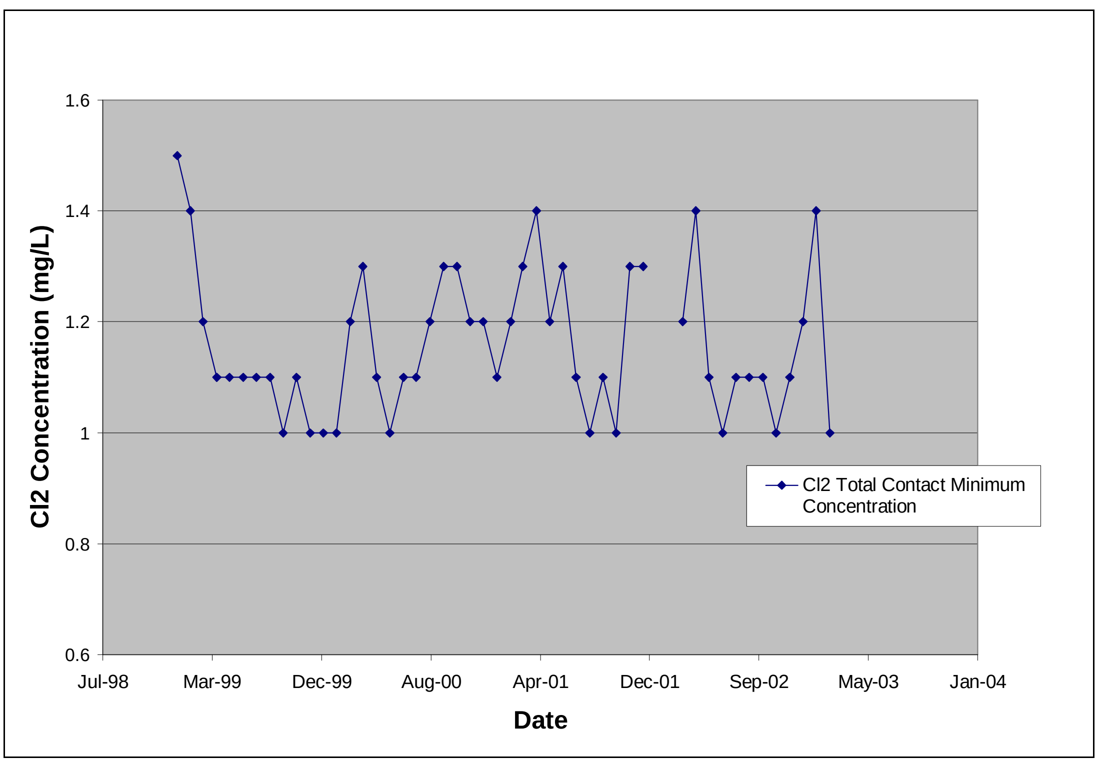


Figure 3-17: Thousand Trails Lynchburg Preserve Cl2 Total Contact Minimum Concentration



3.5.2 Extent of Sanitary Sewer Network

The extent of the sanitary sewer network for the Rustburg WWTP was determined from maps provided by the Campbell County Utility Service Authority. The sewage collected in this network is conveyed to the sewer treatment plant located in the Town of Rustburg. The housing units that are not served by a public sewer rely on septic systems for treatment of household waste. Maps were not available for other permitted facilities in the watershed.

Estimates of the total number of households connected to the sewer system are presented in the next section.

3.5.2.1 Septic Systems

There are no data available for the total number of septic systems in the watershed. Estimates of the total number of housing units located in the watershed and the identification of whether these housing units are connected to a public sewer or on septic systems were based on three sources of data:

- USGS 7.5 minute quadrangle maps
- Campbell County Utility Service Authority maps
- U.S. Census Bureau data

The Campbell and Appomattox USGS 7.5 minute quadrangle maps were combined and used to create a single map covering the entire Falling River watershed. The housing units on the USGS maps were digitized and converted to a GIS layer of the total housing units in the watershed. After combining the housing units GIS layer with the map of the sewer network in the watershed and adjusting for the population growth, it was estimated that there are 6,008 housing units in the watershed. In addition, out of the 1720 connections to the wastewater facilities, only 949 households are located in the watershed. Therefore these 949 households were considered sewered and the remaining 5,055 households were on septic systems. The USGS maps were dated 1964-1967, with photo revision dated 1982-87. Therefore, it was assumed that the 5,055 septic systems are at least 20 years old or more.

The U.S. Census Bureau 2000 data for Campbell and Appomattox counties was reviewed to establish the population growth rates in the counties and to validate the housing units calculation. A summary of the census data is presented in Table 3-10.

Table 3-10: 2000 Census Data Summary for Campbell and Appomattox Counties

U.S. Census Data - 2000	County	
	Campbell	Appomattox
Population	51,078	13,705
# Households	20,639	5,322
# Housing Units	22,088	5,828
Population density (persons per square mile)	101	41
Household density (persons per household)	2.47	2.58

The Census data also indicated that the population growth for Campbell County between 1980 and 1990 was 4.7 percent and between 1990 and 2000 was 7.4 percent. The Census data for Appomattox County indicates a growth rate of 2.7 percent between 1980 and 1990 and 11.4 percent between 1990 and 2000. For this TMDL development, a 7.4 percent population increase in Campbell County and an 11.4 percent increase in Appomattox County were considered to be representative of the population growth in the watershed. The total number of housing units in the watershed was calculated based on the above Census data for Campbell and Appomattox Counties. Taking into account that the watershed makes up about 35 percent of the Campbell County land area and approximately 16 percent of the Appomattox County land area, and assuming growth rates of 7.4 percent and 11.4 percent, respectively, the total number of housing units in the watershed was estimated at 6,008. This assumes that there are new homes in the watershed along major transportation routes, which is true in some cases.

3.5.2.2 Failed Septic Systems

To determine the amount of fecal coliform contributed by human sources, the failure rates of septic systems must be estimated. Septic system failures are generally attributed to the age of a system. For this TMDL model, the failure rates were determined based on the total number of septic systems versus the number of applications for new systems and the number of repairs to existing systems in Campbell and Appomattox counties. Table 3-11 and Table 3-12 show the number of applications for new systems as well as the number of repairs over the last five years in Campbell and Appomattox counties. This data was combined with the population data to establish the rate of applications for new septic systems and the rate of repair of existing septic systems in the watershed. Table 3-13 and Table 3-14 show the rate of applications for new septic systems in Campbell and Appomattox counties ranged from 0.03 to 7.6 percent from 1995 to 2002. For the same period, the data indicate that the rate of septic system repair permits ranged from 0 to 0.71 percent. These septic system failure rates are considered extremely low for an area where many septic systems have been operating for over 20 years. This low rate may be attributed to a large number of septic system repairs being performed without obtaining a permit.

Table 3-11: New Septic Systems and Repair Applications in Appomattox County

Year	Number of Permits/ Applications for New Septic Systems	Number of permits/ applications for Repairs of Existing Septic Systems
1995	60	3
1996	38	5
1997	33	6
1998	56	3
1999	48	3
2000	59	1
2001	54	0
2002	67	0

Table 3-12: New Septic Systems and Repair Applications in Campbell County

Year	Number of Permits/ Applications for New Septic Systems	Number of permits/ applications for Repairs of Existing Septic Systems
1995	18	10
1996	40	9
1997	41	9
1998	36	7
1999	37	6
2000	22	8
2001	24	7
2002	2	4

Table 3-13: New Septic Systems and Repair Applications Rates in Appomattox County

Year	Total Households in Appomattox County*	% New	% Repair
1995	825	7.3	0.36
1996	831	4.6	0.60
1996	840	3.9	0.71
1998	852	6.6	0.35
1999	863	5.6	0.35
2000	852	6.9	0.12
2001	894	6.0	0.00
2002	887	7.6	0.00

*Calculations based on 2.57 persons per household for Appomattox County from 2000 census.

Table 3-14: New Septic Systems and Repair Applications Rates in Campbell County

Year	Total Households in Campbell County*	% New	% Repair
1995	6,706	0.27	0.15
1996	6,742	0.59	0.13
1997	6,799	0.60	0.13
1998	6,810	0.53	0.10
1999	6,843	0.54	0.09
2000	7,224	0.30	0.11
2001	6,954	0.35	0.10
2002	6,996	0.03	0.06

*Calculations based on 2.47 persons per household for Campbell County from 2000 census.

A detailed discussion of septic failure rates, flow, and fecal coliform concentrations is presented in Chapter 4.

3.5.3 Livestock

An inventory of the livestock residing in the Falling River watershed was conducted using data and information provided from the DCR, Robert E. Lee Soil and Water Conservation District, NRCS, and field surveys. The data and information indicate the following:

- beef cattle exist on the pasture areas of the watershed
- five dairy operations exist in the watershed
- no poultry operations exist in the watershed
- no swine operations exist in the watershed
- no feedlots are located in the watershed
- alternative water has been implemented in the watershed to minimize livestock activity in the streams

Table 3-15 summarizes the livestock inventory in the watershed.

Table 3-15: Falling River Watershed Livestock Inventory

Livestock Type	Total Number of Animals
Beef Cattle	5,000
Dairy Cattle	513

Sources: DCR, Robert E. Lee Soil & Water Conservation District, field surveys, Falling River stakeholders

The livestock inventory was used to determine the fecal coliform loading by livestock in the watershed. Table 3-16 shows the average fecal coliform production per animal per day contributed by each type of livestock.

Table 3-16: Daily Fecal Coliform Production of Livestock

Source	Daily Fecal Production (in millions of cfu/day)
Beef Cattle	33,000
Dairy Cattle: Milked or Dry Cow	25,200
Dairy Cattle: Heifer	11,592
Horse	420
Goat	27,000
Sheep	27,000

Sources: ASAE, 1998; Metcalf and Eddy, 1979; Map Tech, Inc., 2000; EPA, 2001.

The impact of fecal coliform loading from livestock is dependent upon whether loadings are directly deposited into the stream, or indirectly delivered to the stream via surface runoff. For this TMDL, fecal coliform deposited while livestock were in confinement or grazing was considered indirect deposit, and fecal coliform deposited when livestock directly defecate into the stream was considered direct deposit. The distribution of daily fecal coliform loading between direct and indirect deposits was based on livestock daily schedules.

For the Falling River TMDL, the initial estimates of the beef cattle daily schedule were based on the Dodd Creek TMDL. The amount of time beef cattle spend in the pasture and stream was also presented during the public meetings where stakeholders provided comments. The monthly schedule was adjusted to reflect the conditions in the watershed.

The daily schedule for beef cattle that was accepted by the stakeholders is presented in Table 3-17. The daily schedule for dairy cows that was accepted by the stakeholders is presented in Table 3-18. The time beef cattle and dairy cows spend in the pasture or loafing was used to determine the fecal coliform load deposited indirectly. The directly deposited fecal coliform load from livestock was based on the amount of time they spend in the stream.

Table 3-17: Daily Schedule for Beef Cattle

Month	Time Spent in		
	Pasture (Hour)	Stream (Hour)	Loafing Lot (Hour)
January	23.50	0.50	0
February	23.50	0.50	0
March	23.25	0.75	0
April	23.00	1.00	0
May	23.00	1.00	0
June	22.75	1.25	0
July	22.75	1.25	0
August	22.75	1.25	0
September	23.00	1.00	0
October	23.25	0.75	0
November	23.25	0.75	0
December	23.50	0.50	0

Source: Dodd Creek TMDL Report, DCR 2002.

Table 3-18: Daily Schedule for Dairy Cows

Month	Time Spent in		
	Pasture (Hour)	Stream (Hour)	Loafing Lot (Hour)
January	7.45	0.25	16.30
February	7.45	0.25	16.30
March	8.10	0.50	15.40
April	9.35	0.75	13.90
May	10.05	0.75	13.20
June	10.30	1.00	12.70
July	10.80	1.00	12.20
August	10.80	1.00	12.20
September	11.05	0.75	12.20
October	11.00	0.50	12.50
November	10.30	0.50	13.20
December	9.15	0.25	14.60

Source: Dodd Creek TMDL Report, DCR 2002.

3.5.4 Land Application of Manure

Land application of the manure that cattle produce while in confinement is a typical agricultural practice. Both diary operations and beef cattle are present in the watershed. Because there are no recorded feedlots, or a significant number of manure storage facilities present in the watershed, the manure produced by confined livestock was directly applied on the pasturelands, and was treated as an indirect source in the development of the Falling River TMDL.

3.5.5 Land Application of Biosolids

Non-point human sources of fecal coliform can be associated with the spreading of biosolids. Discussions with Virginia DOH indicated that there has not been any permitted spreading of biosolids in Campbell County, but some biosolids land application has occurred in Appomattox County (Charlie Swanson, written communication). In 2002, 2,430 dry tons of biosolids were applied to 1,565 acres in Appomattox County. In 2003, 8,366 dry tons of biosolids were applied in Appomattox County, although data on the numbers of acres on which biosolids were applied were not available. The biosolids that were applied in Appomattox County had a fecal coliform content of 2 counts per gram of dry solids, which is less than the fecal coliform in average soil (Charlie Swanson, written communication). Therefore, application of biosolids was not considered in development of the Falling River TMDL.

3.5.6 Wildlife

Similar to livestock contributions, wildlife contributions of fecal coliform can be both indirect and direct. Indirect sources are those that are carried to the stream from the surrounding land via rain and runoff events, whereas direct sources are those that are directly deposited into the stream.

The wildlife inventory for this TMDL was developed based on a number of information and data sources, including: (1) habitat availability, (2) Department of Game and Inland Fisheries (DGIF) harvest data and population estimates, and (3) stakeholder comments and observations.

A wildlife inventory was conducted based on habitat availability within the watershed. The number of animals in the watershed was estimated by combining typical wildlife densities with available stream wildlife habitat. Typical wildlife densities are presented in Table 3-19.

Table 3-19: Wildlife Densities

Wildlife type	Population Density	Habitat Requirements
Deer	0.047 animals/acre	Entire watershed
Raccoon	0.07 animals/acre	Within 600 feet of streams and ponds
Muskrat	2.75 animals/acre	Within 66 feet of streams and ponds
Beaver	4.8 animals/mile of stream	
Goose	0.004 animals/acre	Within 66 feet of streams and ponds
Mallard	0.002 animals/acre	Entire Watershed
Wood Duck	0.0018 animals/acre	Within 66 feet of streams and ponds
Wild Turkey	0.01 animals/acre	Entire watershed excluding farmsteads and urban land uses

Source: Map Tech, Inc., 2001.

The wildlife inventory presented in Table 3-20 was then confirmed with DGIF and DCR, and was presented to stakeholders and local residents for approval.

Table 3-20: Falling River Watershed Wildlife Inventory

Wildlife type	Number of Animals
Deer	7,104
Raccoon	3,531
Muskrat	15,260
Beaver	1,665
Goose	22
Mallard	11
Wood duck	10
Wild Turkey	1,497

The wildlife inventory was used to determine the fecal coliform loading by wildlife within the watershed. Table 3-21 shows the average fecal coliform production per animal, per day, contributed by each type of wildlife. Separation of the wildlife daily fecal coliform load into direct and indirect deposits was based on estimates of the amount of time each type of wildlife spends on land versus time spent in the stream. Table 3-21 also shows the percent of time each type of wildlife spends in the stream on a daily basis.

Table 3-21: Fecal Coliform Production from Wildlife

Wildlife	Daily Fecal Production (in millions of cfu/day)	Portion of the Day in Stream (%)
Deer	347	1
Raccoon	113	10
Muskrat	25	50
Goose	799	50
Beaver	0.2	90
Mallard	2,430	50
Wood Duck	2,430	75
Wild Turkey	93	5

Source: ASAE, 1998; Map Tech, Inc., 2000; EPA, 2001.

3.5.7 Pets

The contribution of fecal coliform loading from pets was also examined in the assessment of fecal coliform loading to Falling River. The primary types of pets considered in this TMDL are cats and dogs. The number of pets residing in the Falling River watershed was estimated based on the number of households in the watershed, assuming an average of 1.7 dogs and 2.2 cats per household. As previously presented, the total number of households in the watershed was estimated to be 6,008. Therefore it was estimated that a total of 13,218 cats and 10,214 dogs were present in the watershed.

Fecal coliform loading from pets occurs primarily in residential areas. The load was estimated based on daily fecal coliform production rates of 504 cfu/day per animal for cats and 4.09 x10^9 cfu/day per animal for dogs.

3.6 Existing Best Management Practices

Information about the existing best management practices (BMPs) in the Falling River watershed was compiled during interviews with the NRCS, SWCD, and DCR staff. The BMP information compiled from the interviews was compared to BMP GIS data obtained from DCR. Table 3-22 is a list of the BMP types present in the Falling River watershed. Figure 3-18 presents the location of these BMPs in the watershed.

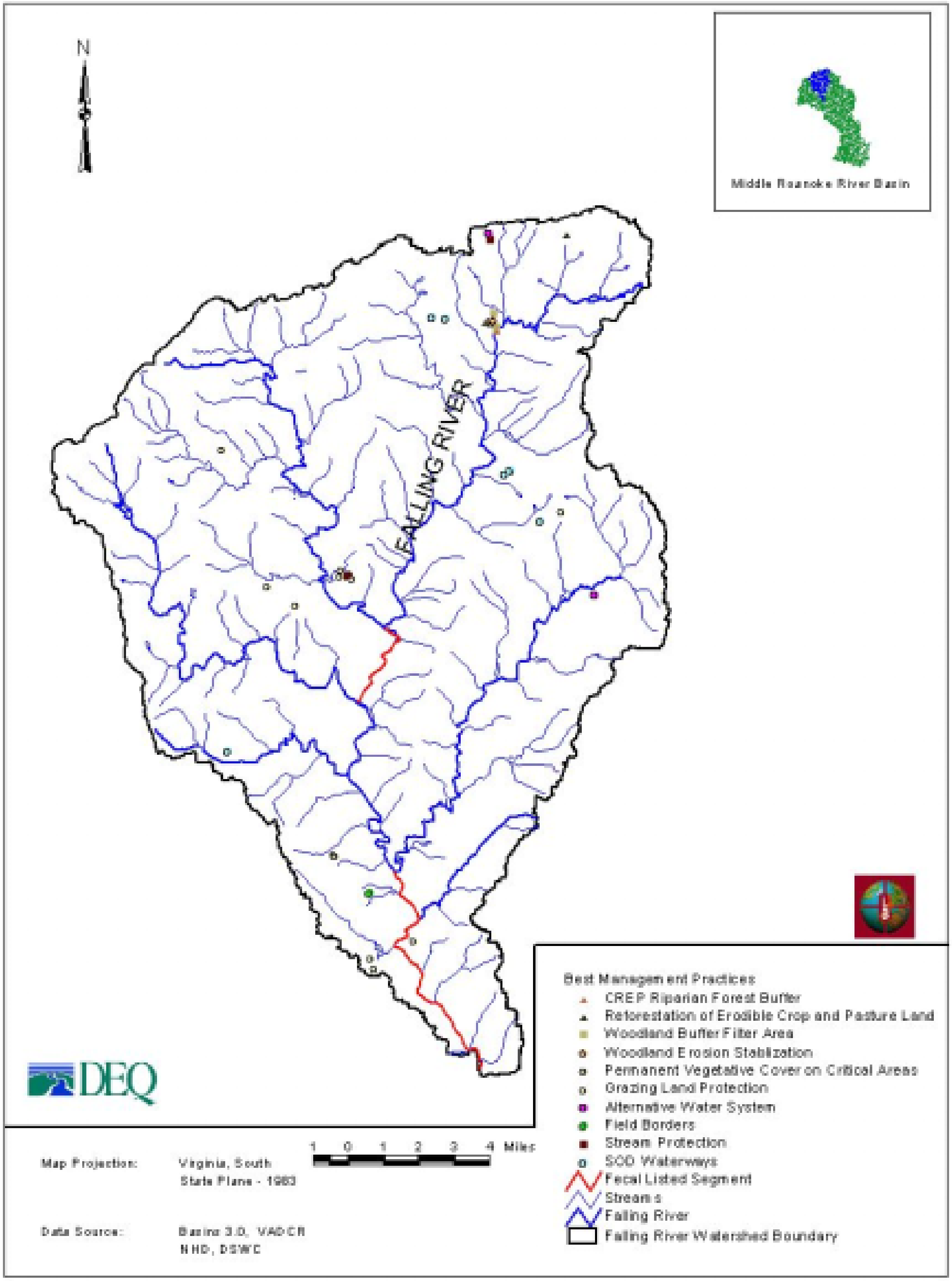
The most common BMPs present in the Falling River watershed include Sod Waterways, Reforestation of Erodible Crop and Pasture Land, CREP Riparian Forest Buffer, Woodland Buffer Filter Area, and Stream Protection.

Table 3-22: Inventory of Existing BMPs in the Falling River Watershed

BMP	Code[1]	Number
CREP Riparian Forest Buffer	CP-22	3
Reforestation of Erodible Crop and Pasture Land	FR-1	4
Woodland Buffer Filter Area	FR-3	3
Woodland Erosion Stabilization	FR-4	1
Permanent Vegetative Cover on Critical Areas	SL-11	2
Grazing Land Protection	SL-6	2
Alternative Water System	SL-6B	2
Field Borders	WL-1	1
Stream Protection	WP-2	3
SOD Waterways	WP-3	7

1: The BMP codes are defined in Virginia Agricultural BMP Manual, 2003, Department of Conservation and Recreation, Richmond, VA.
Source: DCR, 2003.

Figure 3-18: Best Management Practices (BMPs) in Falling River Watershed



4.0 Modeling Approach

This section describes the modeling approach used in the Falling River TMDL development. The primary focus is on the sources represented in the model, assumptions used, model set-up, calibration, and validation, and the existing load.

4.1 Modeling Goals

The goals of the modeling approach were to develop a predictive tool for the water body that can:

- represent the watershed characteristics
- represent the point and non-point sources of fecal coliform and their respective contribution
- use input time series data (rainfall and flow) and kinetic data (die-off rates of fecal coliform)
- estimate the in-stream pollutant concentrations and loadings under the various hydrologic conditions
- allow for direct comparisons between the in-stream conditions and the water quality standard

4.2 Model Selection

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the in-stream water quality conditions of Falling River under varying scenarios of rainfall and fecal coliform loading. The results from the developed Falling River model were used to develop the TMDL allocations based on the existing fecal coliform load.

HSPF is a hydrologic, watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineating the watershed into smaller subwatersheds
- entering the physical data that describe each subwatershed and stream segment
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

These steps are discussed in the next few sections.

4.3 Watershed Boundaries

Falling River is a part of the Middle Roanoke River Basin. The Falling River watershed is approximately 151,000 acres, or 236 square miles. The watershed is located within Campbell and Appomattox Counties, Virginia. About 75 percent of the total watershed is located in Campbell County; the remaining 25 percent is located in Appomattox County. The watershed comprises approximately 35 percent of the land area in Campbell County, and 16 percent of the land area in Appomattox County. State Highway 501 (SH-501) runs along the western boundary of the watershed in a north to south direction. U.S. Highway 24 (US-24) runs along the northern boundary of the watershed in a west to northeast direction. U.S. Highway 40 (US-40) passes through the lower section of the watershed in an east to west direction. State Highway 460 (SH-460) goes along a portion of the northern boundary of the watershed in an east to north direction. Figure 4-1 is a map showing the Falling River watershed boundaries.

4.4 Watershed Delineation

For this TMDL, the Falling River watershed was delineated into 20 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. This delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data. Size distributions of the 20 subwatersheds are presented in Table 4-1. Figure 4-2 is a map showing the delineated subwatersheds for Falling River.

Figure 4-1: Falling River Watershed Boundary

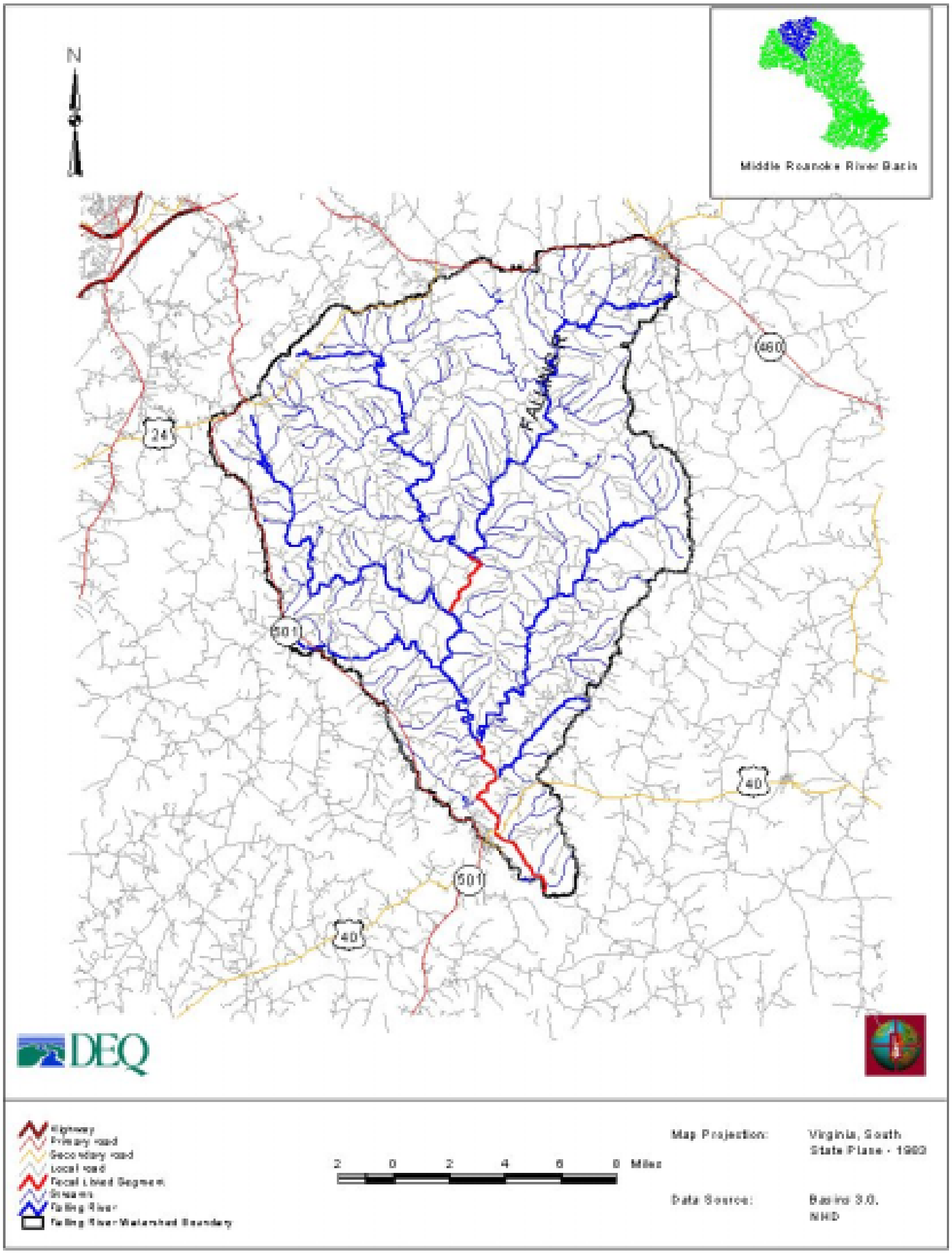
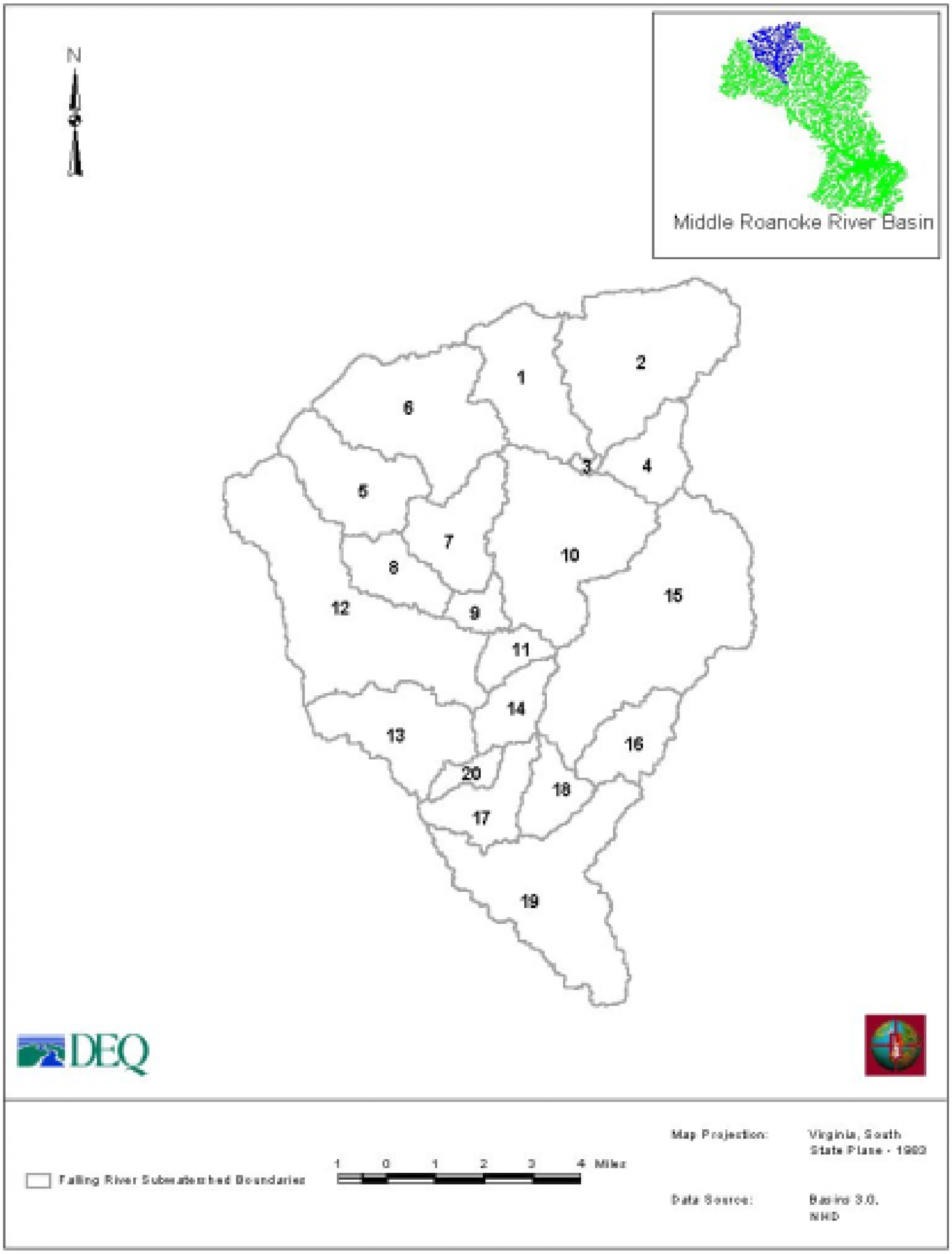


Table 4-1: Falling River Delineated Subwatersheds

Subwatershed	Drainage Area (acres)
1	8,065
2	13,628
3	400
4	3,778
5	7,399
6	11,989
7	5,843
8	3,863
9	14,416
10	1,640
11	2,033
12	19,195
13	7,733
14	3,192
15	20,864
16	4,198
17	3,521
18	3,005
19	14,091
20	2,084
Total	**150,937**

Figure 4-2: Falling River Subwatershed Delineation



4.5 Land Use Reclassification

As previously mentioned, land use distribution in the Falling River Watershed was determined using USGS NLCD data. The land use data and distribution of land uses in the Falling River watershed were presented in Chapter 3. There are 12 land use classes present in the Falling River watershed; the dominant land uses are forested land and hay/pastureland. The original 12 land use types were consolidated into 8 land use categories to meet modeling goals, facilitate model parameterization, and reduce modeling complexity. This reclassification reduced the 12 land use types to a representative number of categories that best describe conditions and the dominant fecal coliform source categories in the Falling River watershed. Land use reclassification was based on similarities in hydrologic characteristics and potential fecal coliform production characteristics. The reclassified land uses are presented in Table 4-2.

Table 4-2: Falling River Land Use Reclassification

Land Use Category	Land Use Type	Acres	Percent of Watershed's Land Area
Water	Open Water	832.5	0.55
Low Residential	Low Intensity Residential	1246.1	0.82
High Residential	High Intensity Residential	2.4	0.002
Commercial/Industrial/ Transportation	Commercial/Industrial/Transportation	260.5	0.17
Cropland	Row Crop	4337.0	2.87
Pasture	Pasture/Hay	38377.4	25.48
	Transitional	3464.6	2.29
Forest	Deciduous Forest	61591.7	40.74
	Evergreen Forest	17524.8	11.59
	Mixed Forest	22411.4	14.82
Wetlands	Woody Wetlands	998.4	0.66
	Emergent Herbaceous Wetlands	148.9	0.10
Total		**151,196**	**100**

4.6 Hydrographic Data

Hydrographic data describing the stream network of Falling River were obtained from the National Hydrography Dataset (NHD) and the Reach File Version 3 (RF3) dataset contained in BASINS. These data were used for HSPF model development and TMDL development. Information regarding the reach number, reach name, and length of each stream segment of Falling River are included in the RF3 database. Reach information for stream segments comprising the mainstem Falling River are provided in Table 4-3. Due to the size of this basin, reach information for the entire Falling River drainage is not presented in this report.

Table 4-3: Mainstem Falling River RF3 Reach Information

Reach Number	Reach Name	Length (miles)
3010102 51 4.24	Falling River	0.59
3010102 46 2.39	Falling River	1.22
3010102 51 0.00	Falling River	0.69
3010102 46 5.83	Falling River	0.91
3010102 48 1.33	Falling River	1.19
3010102 51 1.03	Falling River	1.21
3010102 48 2.26	Falling River	0.60
3010102 48 0.00	Falling River	0.47
3010102 46 0.72	Falling River	0.12
3010102 51 0.62	Falling River	0.42
3010102 5110.65	Falling River	1.04
3010102 51 7.40	Falling River	0.66
3010102 51 3.29	Falling River	1.05
3010102 51 4.78	Falling River	0.73
3010102 51 8.00	Falling River	1.10
3010102 46 0.23	Falling River	0.50
3010102 46 0.83	Falling River	1.61
3010102 46 3.59	Falling River	1.10
3010102 46 4.66	Falling River	1.20
3010102 46 6.98	Falling River	0.73
3010102 48 0.27	Falling River	1.52
3010102 48 1.14	Falling River	0.34
3010102 48 2.01	Falling River	0.43
3010102 49 0.75	Falling River	1.24
3010102 51 2.13	Falling River	0.23
3010102 51 2.33	Falling River	0.81
3010102 51 3.06	Falling River	0.26
3010102 51 5.44	Falling River	0.47
3010102 51 5.86	Falling River	1.70
3010102 51 9.64	Falling River	0.90
3010102 5111.77	Falling River	1.33
3010102 5113.58	Falling River	0.88

The stream geometry was field surveyed for representative reaches of Falling River. The stage flow relationship that is required by HSPF was developed based on the USGS stream flow gage data for Falling River.

Falling River and its tributaries were represented as trapezoidal channels. The channel slopes were estimated using the reach length and the corresponding change in elevation from DEM data. The flow was calculated using the Manning's equation using a 0.05 roughness coefficient. Model representation of the Falling River stream reach segments is presented in Appendix A.

4.7 Fecal Coliform Sources Representation

This section demonstrates how the fecal coliform sources identified in Chapter 3 were included or represented in the model. These sources include permitted sources, human sources (failed septic systems and straight pipes), livestock, wildlife, pets, and land application of manure and biosolids.

4.7.1 Permitted Facilities

There are 7 permitted dischargers in the Falling River watershed. Table 4-4 shows the permitted facility identification number, the stream reach receiving the discharge, facility design flow, and the permitted fecal coliform concentration.

Table 4-4: Permitted Dischargers in the Falling River Watershed

Permit Number	Facility Name	Receiving Stream Reach	Design Flow (gpd)[1]	Fecal Coliform Concentration (cfu/100ml)	Status
VA0020249	Appomattox STP	Caldwells Creek (3010102 993 0.00)	170,000	200	Active
VA0022250	Town of Brookneal - Lagoon	Falling River (3010102 46 2.39)	82,000	200	Active
VA0023396	DOC Rustburg	UT- Buttom Creek (3010102 1037 0.00)	28,000	200	Active
VA0023965	Rustburg WWTP	Mollys Creek (3010102 53 13.34)	200,000	200	Active
VA0068543	Thousand Trails Lynchburg Preserve	Mollys Creek (3010102 53 8.73)	39,600	200	Active
VA0084034	Brookneal WTP	Phelps Creek (3010102 1073 0.00)	41,000		Active
VA0084034	Brookneal WTP	Phelps Creek (3010102 1073 0.00)	600		Active
VA0089478	Gladys Timber Products	Suck Creek (3010102 54 5.96)	200,000		Active

1. gpd: gallons per day

For TMDL development, mean flow values were considered representative of flow conditions at each permitted facility, and were used in HSPF model set-up and calibration.

For TMDL allocation development, permitted facilities were represented as constant sources discharging at their design flow and permitted fecal coliform concentrations.

4.7.2 Failed Septic Systems

Failed septic system loading to Falling River can be direct (point) or land-based (indirect or non-point), depending on the proximity of the septic system to the stream. In cases where the septic system is within the 20-foot stream buffer, the failed septic system was represented in the model as a constant source (similar to a permitted facility). As explained in Chapter 3, the total number of septic systems in the watershed was estimated at 5,055 systems. Based on GIS data, only 9 of the 5,055 households on septic systems were located in the 20-foot stream buffer. Therefore the failed septic system load was considered a land-based load in the Falling River watershed.

For TMDL development, it was assumed that a 3% failure rate for septic systems would be representative of conditions in the watershed. This corresponds to a total of 152 failed septic systems in the watershed. To account for uncontrolled discharges in the watershed and failed septic systems within the stream buffer, a total of 15 straight pipes were included in the model. This estimate was based on field observations, discussions with DCR and DEQ, stakeholder comments, evaluation of the BST results, and 1990 Census data which indicated that approximately 16% of households in the watershed are on other treatment systems.

In each subwatershed, the load from failing septic systems was calculated as the product of the total number of septic systems, septic systems failure rate, flow rate of septic discharge, typical fecal concentration in septic outflow, and the average household size in the watershed. The septic systems' design flow of 75 gallons per person per day and a fecal coliform concentration of 10,000 cfu/100ml were used in the fecal coliform load calculations. Fecal coliform loading from failed septic systems that are not within the 20 buffer of the stream is considered to be a predominantly indirect source. Failed septic systems within the stream buffer and straight pipes were represented as constant sources of fecal coliform. Table 4-5 shows the distribution of the septic systems and the straight pipes in the Falling River watershed. The load from septic systems is presented in Appendix B.

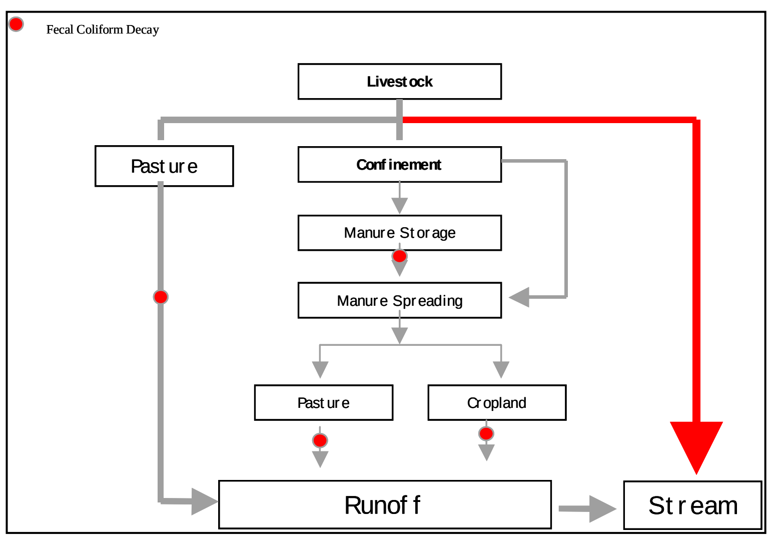
Table 4-5: Failed Septic Systems and Straight Pipes Assumed in Model Development

Subwatershed ID	Number of septic systems	Number of Failed Septic Systems	Number of straight pipes
1	158	5	1
2	737	22	2
3	2	0	0
4	77	2	0
5	340	10	1
6	493	15	1
7	185	6	1
8	145	4	0
9	46	1	0
10	323	10	1
11	56	2	0
12	821	25	2
13	275	8	1
14	49	2	0
15	389	12	1
16	144	4	0
17	170	5	1
18	141	4	0
19	458	14	3
20	46	1	0
Total	5,055	152	15

4.7.3 Livestock

Livestock contribution to the total fecal coliform load in the watershed was represented in a number of ways, which are presented in Figure 4-3. The model accounts for fecal coliform directly deposited in the stream, fecal coliform deposited while livestock are in confinement and later spread onto the crop and pasture lands in the watershed (land application of manure), and finally, land-based fecal coliform deposited by livestock while grazing.

Figure 4-3: Livestock Contribution to Falling River Watershed



Based on the inventory of livestock in the Falling River watershed, it was determined that beef cattle are the predominant type of livestock, though dairy cows are also present in the watershed. The inventory also indicated that there are no horses, goats, poultry operations, sheep, swine or feedlots in the watershed. Five dairy operations exist in the watershed. The survey also indicated that alternative water has been implemented in the Falling River watershed to minimize livestock activity in the stream.

The distribution of the daily fecal coliform load between direct in-stream and indirect (land-based) loading was based on livestock daily schedules. The direct deposition load from livestock was estimated from the number of livestock in the watershed, the daily fecal coliform production per animal, and the amount of time livestock spent in the stream. The amount of time livestock spend in the stream was presented in Chapter 3.

The land-based load of fecal coliform from livestock while grazing was determined based on the number of livestock in the watershed, the daily fecal coliform production per animal, and the percent of time each animal spends in pasture. The monthly loading rates are presented in Appendix B.

4.7.4 Land Application of Manure

Beef cattle, as well as several dairy operations, are present in the Falling River watershed. Because there are no feedlots or large manure storage facilities present in the watershed, the daily produced manure is applied to pastureland in the watershed, and was treated as an indirect source in the development of the Falling River TMDL. Beef cattle spend the majority of their time on pastureland and are not confined. Thus, fecal coliform loading from beef cattle was accounted for via the methods described above. Dairy cattle do spend time in confinement, and their fecal coliform load was included in the calculation of land application of manure. Fecal coliform loading from land application of manure was estimated based on the total number of dairy cows in the watershed, the fecal coliform production per animal per day, and the percent of time dairy cows were in confinement.

4.7.5 Land Application of Biosolids

Because the biosolids spread in the Falling River watershed had a fecal coliform content less than that of average soil, it was not considered in development of the Falling River TMDL.

4.7.6 Wildlife

Fecal loading from wildlife was estimated in the same way as loading from livestock. As with livestock, fecal coliform contributions from wildlife can be both indirect and direct. The distribution between direct and indirect loading was based on estimates of the amount of time each type of wildlife spends on the surrounding land versus in the stream.

Daily fecal coliform production per animal and the amount of time each type of wildlife spends in the stream was presented previously in the wildlife inventory (Chapter 3). The direct fecal coliform load from wildlife was calculated by multiplying the number of each type of wildlife in the watershed by the fecal coliform production per animal per day, and by the percentage of time each animal spends in the stream. Indirect (land-based) fecal coliform loading from wildlife was estimated as the product of the number of each type of wildlife in the watershed, the fecal coliform production per animal per day, and the percent of time each animal spends on land within the Falling River watershed. The resulting fecal coliform load was then distributed to forest and pasture land uses, which represent the most likely areas in the watershed where wildlife would be present and defecate. This was accomplished by converting the indirect fecal coliform load to a unit loading (cfu/acre), then multiplying the unit loading by the total area of forest and pasture in each subwatershed. Fecal coliform loading from wildlife is presented in Appendix B.

4.7.7 Pets

For the Falling River TMDL, pet fecal coliform loading was considered a land-based load that was primarily deposited in residential areas of the watershed. The daily fecal coliform loading was calculated as the product of the number of pets in the watershed and the daily fecal coliform production per type of pet.

4.8 Fecal Coliform Die-off Rates

Representative fecal coliform decay rates were included in the HSPF model developed for the Falling River watershed. Three fecal coliform die-off rates required by the model to accurately represent watershed conditions included:

1. **In-storage fecal coliform die-off**. Fecal coliform concentrations are reduced while manure is in storage facilities.

2. **On-surface fecal coliform die-off**. Fecal coliform deposited on the land surfaces undergoes decay prior to being washed into streams.

3. **In-stream fecal coliform die-off**. Fecal coliform directly deposited into the stream, as well as fecal coliform entering the stream from indirect sources, will also undergo decay.

In the Falling River TMDL, in-storage die-off was not included in the model because there is no manure storage facility located in the watershed. Decay rates of 1.37 and 1.152 per day were used to estimate die-off rates for on-surface and in-stream fecal coliform, respectively (EPA, 1985).

4.9 Model Set-up, Calibration, and Validation

Hydrologic calibration of the HSPF model involves the adjustment of model parameters to control various flow components (e.g. surface runoff, interflow and base flow, and the shape of the hydrographs) and make simulated values match observed flow conditions during the desired calibration period.

The model credibility and stakeholder faith in the outcome hinges on developing a model that has been calibrated and validated. Model calibration is a reality check. The calibration process compares the model results with observed data to ensure the model output is accurate for a given set of conditions. Model validation establishes the model's credibility. The validation process compares the model output to the observed data set, which is different from the one used in the calibration process, and estimates the model's prediction accuracy. Water quality processes were calibrated following calibration of the hydrologic processes of the model.

4.9.1 Model Set-Up

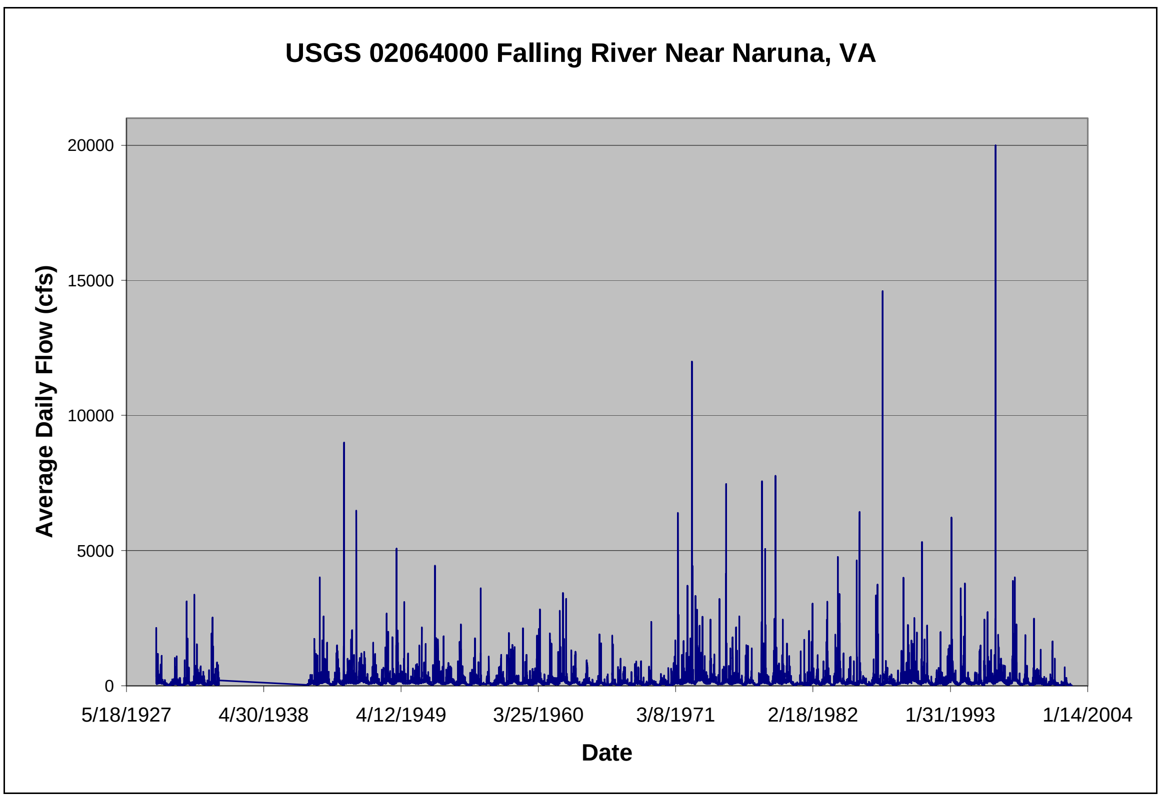
The HSPF model was set up and calibrated based on Falling River flow data taken at USGS station #2064000, where hourly flow data is available.

4.9.1.1 Stream Flow Data

Stream flow data for the Falling River watershed was available from USGS station #2064000, near Naruna. These data were used in TMDL development. The Falling River stream flow station has a period of record from 1929 to 2003. The drainage area above the station is approximately 173 square miles. Average flow data for the period of 1990 to 2002 were retrieved, and are plotted in Figure 4-4. Average flows of Falling River ranged from 1 to 20,000 cfs, with a mean flow of 153.44 cfs.

Stream flow data from USGS station #2064000 were used to set-up and calibrate the hydrological processes of the HSPF model.

Figure 4-4: Daily Mean Flow (cfs) at USGS Gauging Station #2064000

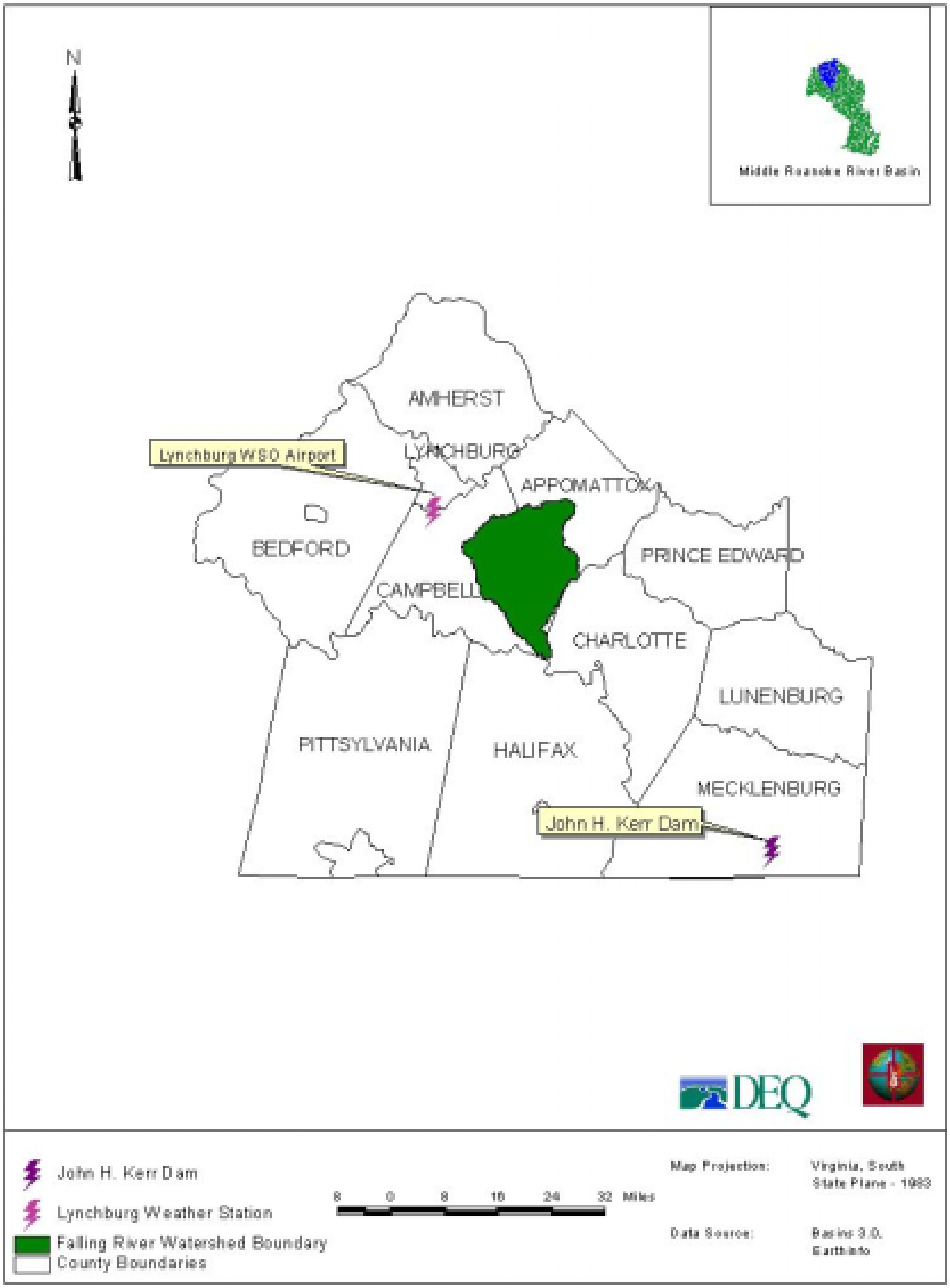


A 4-year period (1997-2000) was selected as the calibration period for the Falling River model.

4.9.1.2 Rainfall and Climate Data

Weather data for the Lynchburg, VA WSO Airport and the John H. Kerr dam were obtained from NCDC. The data include meteorological data (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation). The Lynchburg airport recorded data from 1952 to 2001, and the John H. Kerr dam recorded data from 1948 to the present. For this TMDL, the recorded data at Lynchburg and the Kerr dam were combined based on their proximity to the Falling River watershed. The combined record consisted of 75 percent Lynchburg weather data and 25 percent of the weather data obtained from the John H. Kerr dam. Figure 4-5 depicts the location of the weather stations.

Figure 4-5: Location of Rainfall Stations



4.9.2 Model Hydrologic Calibration Results

HSPEXP software was used to calibrate the Falling River watershed. After each iteration of the model, summary statistics were calculated to compare model results with observed values, in order to provide guidance on parameter adjustment according to built-in rules. The rules were derived from the experience of expert modelers and listed in the HSPEXP user manual (Lumb and Kittle, 1993).

Using the recommended default criteria as target values for an acceptable hydrologic calibration, the Falling River model was calibrated for January 1997 to December 1998. Calibration results are presented in Table 4-6, showing the simulated and observed values for nine flow characteristics. An error statistics summary for seven flow conditions is presented in Table 4-7. The breakdown of the overall percent base, storm and interflow contribution is presented in Table 4-8. The model results and the observed daily average flow at the Falling River station are plotted in Figure 4-6.

Table 4-6: Falling River Model Calibration Results

Category	Simulated	Observed
Total simulated in-stream flow (cfs)	33.60	33.08
Total of highest 10% flows, in inches	15.02	13.75
Total of lowest 50% flows, in inches	5.19	5.48
Total storm volume, in inches	5.55	4.39
Average of storm peaks, in cfs	756.45	570.53
Baseflow recession rate	0.99	0.96
Summer flow volume, in inches	4.75	4.17
Winter flow volume, in inches	11.81	12.46
Summer storm volume, in inches	1.02	0.85

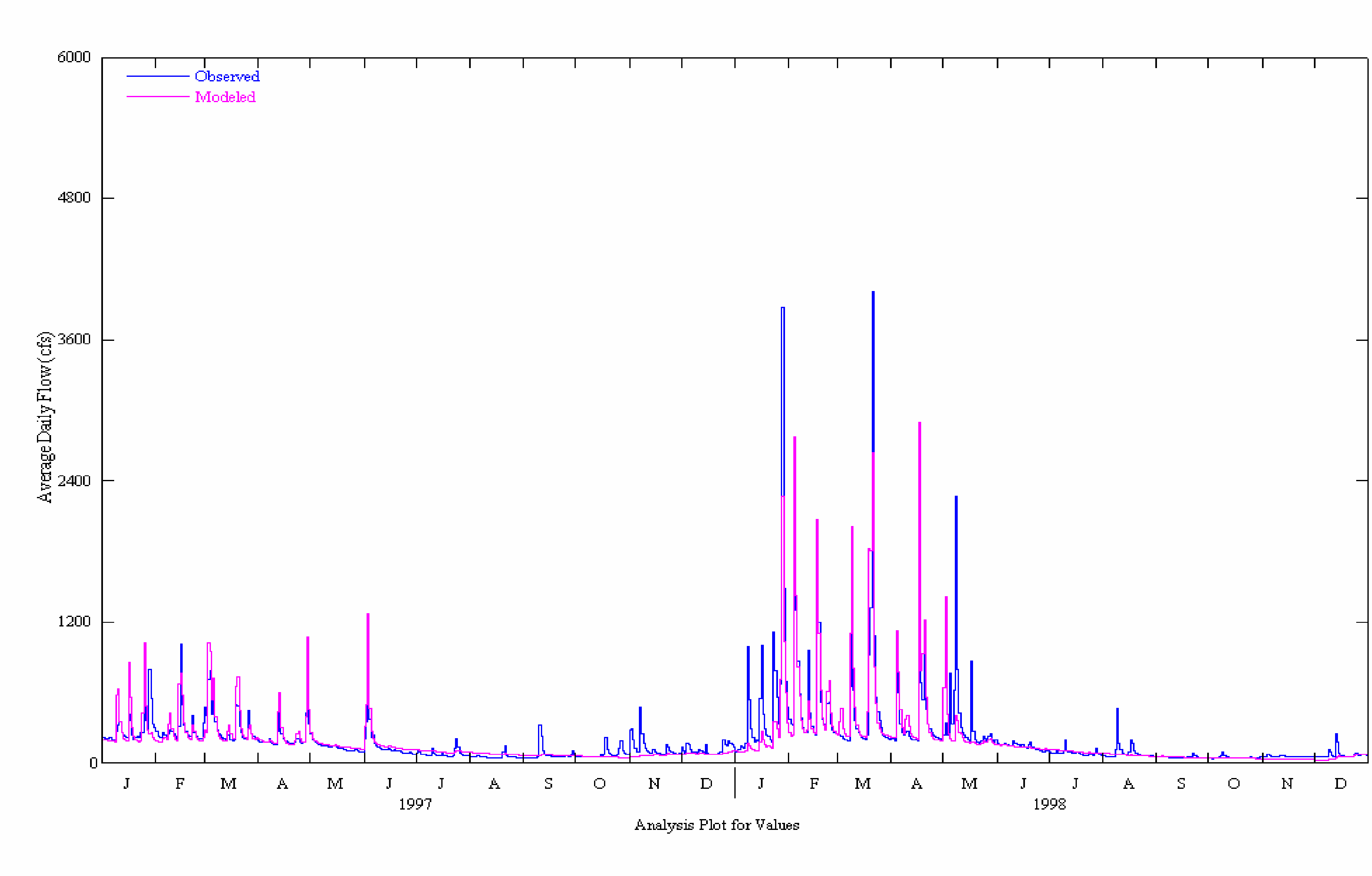
Table 4-7: Falling River Model Calibration Error Statistics

Category	Current	Criterion
Error in total volume	1.6	± 10.000
Error in low flow recession	-3.15	± 15.000
Error in 50% lowest flows	-5.4	± 10.000
Error in 10% highest flows	9.2	± 10.000
Error in storm volumes	32.6	± 10.000
Seasonal volume error	19.2	± 10.000
Summer storm volume error	-6.7	± 10.000

Table 4-8: Falling River Simulation Water Budget

Year	Surface Runoff (inch)	Interflow (inch)	Base flow (inch)	Surface runoff	Interflow	Base flow
1997	1.57	2.25	9.80	11.5	16.5	72.0
1998	4.25	3.99	9.80	23.6	22.1	54.3
Average	**2.91**	**3.12**	**9.80**	**17.5**	**19.3**	**63.1**

Figure 4-6: Falling River HSPF Model Hydrologic Calibration Results



4.9.3 Model Hydrologic Validation Results

The period of January 1996 to December 1996 was used to validate the HSPF model. The validation results are presented in Figure 4-7 and the summary statistics from HSPF are presented in Table 4-9 and Table 4-10. The error statistics indicate that the validation results were within the recommended ranges in HSPF. Comparisons between simulated and observed values for summer storm volume were skewed by an extreme storm event, Hurricane Fran, which occurred from August 23rd to September 6th in 1996. The breakdown of the overall percent base, storm and interflow contribution is presented in Table 4-11.

Table 4-9: Falling River Model Validation Results

Category	Simulated	Observed
Total simulated in-stream flow, in (cfs)	18.30	20.21
Total of lowest 50% flows, in inches	4.87	5.34
Total of highest 10% flows, in inches	6.33	6.68
Total storm volume, in inches	0.95	1.07
Average of storm peaks, in cfs	400.46	439.78
Base flow recession rate	0.98	0.96
Summer flow volume, in inches	2.11	2.84
Winter flow volume, in inches	7.23	7.96
Summer storm volume, in inches	N/A[1]	N/A

[1] Due to the hurricane.

Table 4-10: Falling River Model Validation Error Statistics

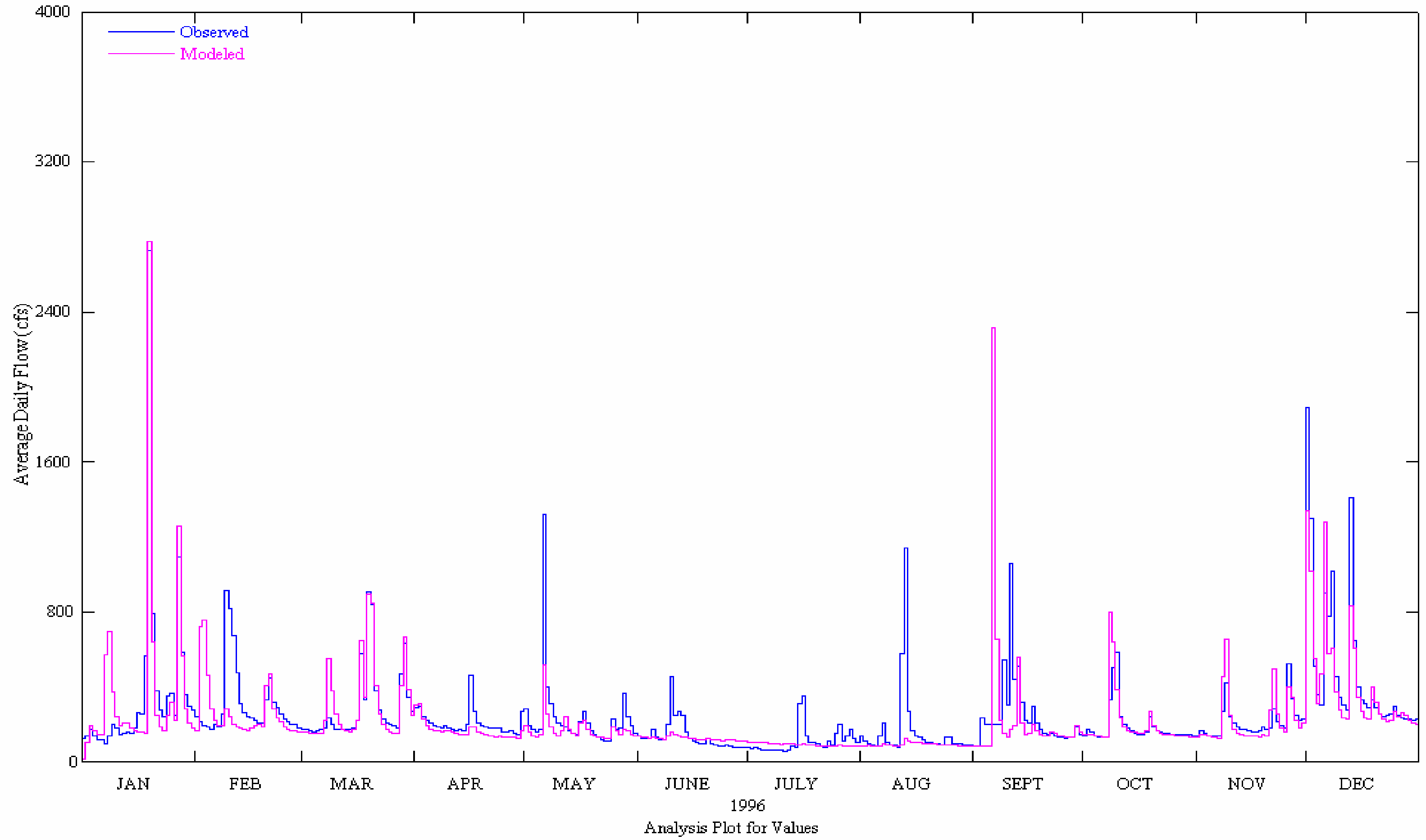
Category	Current	Criteria
Error in total volume	1.60	±10%
Error in low flow recession	0.03	±15%
Error in 50% lowest flows	-5.40	±10%
Error in 10% highest flows	9.20	±10%
Error in storm volumes	44.20	±10%
Seasonal volume error	19.20	±10%
Summer storm volume error	NA[1]	±10%

[1] Due to the hurricane

Table 4-11: Falling River Validation Water Budget

Water Year	Surface Runoff (inch)	Interflow (inch)	Base flow (inch)	Surface runoff	Interflow	Base flow
1996	3.26	3.16	11.7	18.0	17.4	64.6

Figure 4-7: Falling River - HSPF Model Hydrologic Validation Results



There is good agreement between the observed and simulated stream flow, indicating that the model parameterization is representative of the hydrologic characteristics of the watershed. Model results closely match the observed flows during low flow conditions, base flow recession, and storm peaks. The final parameter values of the calibrated model are listed in Table 4-12.

Table 4-12: Falling River Calibration Parameters (Typical, Possible and Final Values)

Parameter	Definition	Units	Typical		Possible		Falling River
			Min	Max	Min	Max	
FOREST	Fraction forest cover	None	0.00	0.5	0	0.95	0-1
LZSN	Lower zone nominal soils moisture	inch	3	8	2	15	1-7
INFILT	Index to infiltration capacity	Inch/hour	0.01	0.25	0.001	0.5	0.09-0.12
LSUR	Length of overland flow	Ft	200	500	100	700	250-300
SLSUR	Slope of overland flowplane	None	0.01	0.15	0.001	0.3	0.0949
KVARY	Groundwater recession variable	1/inch	0	3	0	5	0.1
AGWRC	Basic groundwater recession	None	0.92	0.99	0.85	0.999	0.0989-0.99
PETMAX	Air temp below which ET is reduced	Deg F	35	45	32	48	40
PETMIN	Air temp below which ET is set to zero	Deg F	30	35	30	40	35
INFEXP	Exponent in infiltration equation	None	2	2	1	3	2
INFILD	Ratio of max/mean infiltration capacities	None	2	2	1	3	2
DEEPER	Fraction of groundwater inflow to deep recharge	None	0	0.2	0	0.5	0.1
BASETP	Fraction of remaining ET from base flow	None	0	0.05	0	0.2	0.02
AGWETP	Fraction of remaining ET from active groundwater	None	0	0.05	0	0.2	0

Parameter	Definition	Units	Typical		Possible		Falling River
			Min	Max	Min	Max	
CEPSC	Interception storage capacity	Inch	0.03	0.2	0.01	0.4	0.1
UZSN	Upper zone nominal soils moisture	inch	0.10	1	0.05	2	1.1
NSUR	Manning's n	None	0.15	0.35	0.1	0.5	0.25
INTFW	Interflow/surface runoff partition parameter	None	1	3	1	10	0.65
IRC	Interflow recession parameter	None	0.5	0.7	0.3	0.85	0.5
LZETP	Lower zone ET parameter	None	0.2	0.7	0.1	0.9	0.1
RETSC	Retention storage capacity of the surface	inch					
ACQOP	Rate of accumulation of constituent	#/ac day					2.34E7-3.39E10
SQOLIM	Maximum accumulation of constituent	#					4.69E - 6.77E10
WSQOP	Wash-off rate	Inch/hour					0.60 – 1.0
IOQC	Constituent concentration in interflow	#/CF					1416
AOQC	Constituent concentration in active groundwater	#/CF					283
KS	Weighing factor for hydraulic routing						0.5
FSTDEC	First order decay rate of the constituent	1/day					1.152
THFST	Temperature correction coefficient for FSTDEC	none					1.07

4.9.4 Water Quality Calibration

Calibrating the water quality component of the HSPF model involves setting up the build-up, wash-off, and kinetic rates for fecal coliform that best describe fecal coliform sources and environmental conditions in the watershed. It is an iterative process in which the model results are compared to the available in-stream fecal coliform data, and the model parameters are adjusted until there is an acceptable agreement between the observed and simulated in-stream concentrations and the build-up and wash-off rates are within the acceptable ranges.

The availability of water quality data is a major factor in determining calibration and validation periods for the model. In Chapter 3 in-stream monitoring stations were listed, and sampling events conducted on Falling River were summarized and presented. Three stations, ID #'s 4-AFRV002.78, 4-AFRV017.71, and 4-AMEY016.00, were sampled more than 45 times from 1993-2003. The remaining 4 stations were sampled 20 times or less. Of the frequently sampled stations, station #4-AFRV002.78 was the most downstream, and thus was chosen to calibrate the model.

Station 4-AFRV002.78 was sampled 46 times from 1993 to 2003. Water quality data for this station was retrieved from STORET and DEQ, and was evaluated for potential use in the set-up, calibration, and validation of the water quality model. For the calibration purposes, delineated subwatershed number 19, which contains 3 of the impaired segments (VAC-L34R-03, VAC-L34R-02, and VAC-L34R-01), was modeled and validated against delineated subwatershed number 11, which contains the listed segment VAC-L34R-04. The time period of January 1999 to December 2000 was used for water quality calibration of the model, and the same time period of January 1999 to December 2000 was used for model validation.

It important to keep in mind that the observed fecal coliform concentrations are instantaneous values that are highly dependent on the time and location the sample was collected. The model-simulated fecal coliform concentrations represent the average daily values. Model-simulated results and observed fecal coliform values are plotted and presented in Figure 4-8 and Figure 4-9. The goodness of fit for the water quality calibration was evaluated visually. Analysis of the model results indicated that the model was capable of predicting the range of fecal coliform concentrations under both wet and dry weather conditions, and thus was well-calibrated. Table 4-13 shows the observed and simulated geometric mean fecal coliform concentration over the simulation period. Table 4-14 shows the observed and simulated exceedance rates of the 400 cfu/100 ml instantaneous fecal coliform standard.

Table 4-13: Observed and Simulated Geometric Mean Fecal Coliform Concentration over the Simulation Period.

Segment	Watershed	Geometric Mean (cfu/100ml)	
		Observed	Simulated
19	Falling River	237	286
11	Falling River	175	227

Table 4-14: Observed and Simulated Exceedance Rates of the 400 cfu/100ml Instantaneous Fecal Coliform Standard

Segment	Watershed	Rate of Exceedance	
		Observed	Simulated
19	Falling River	0.28	0.35
11	Falling River	0.13	0.27

Figure 4-8: Falling River Water Quality Calibration (Reach 19)

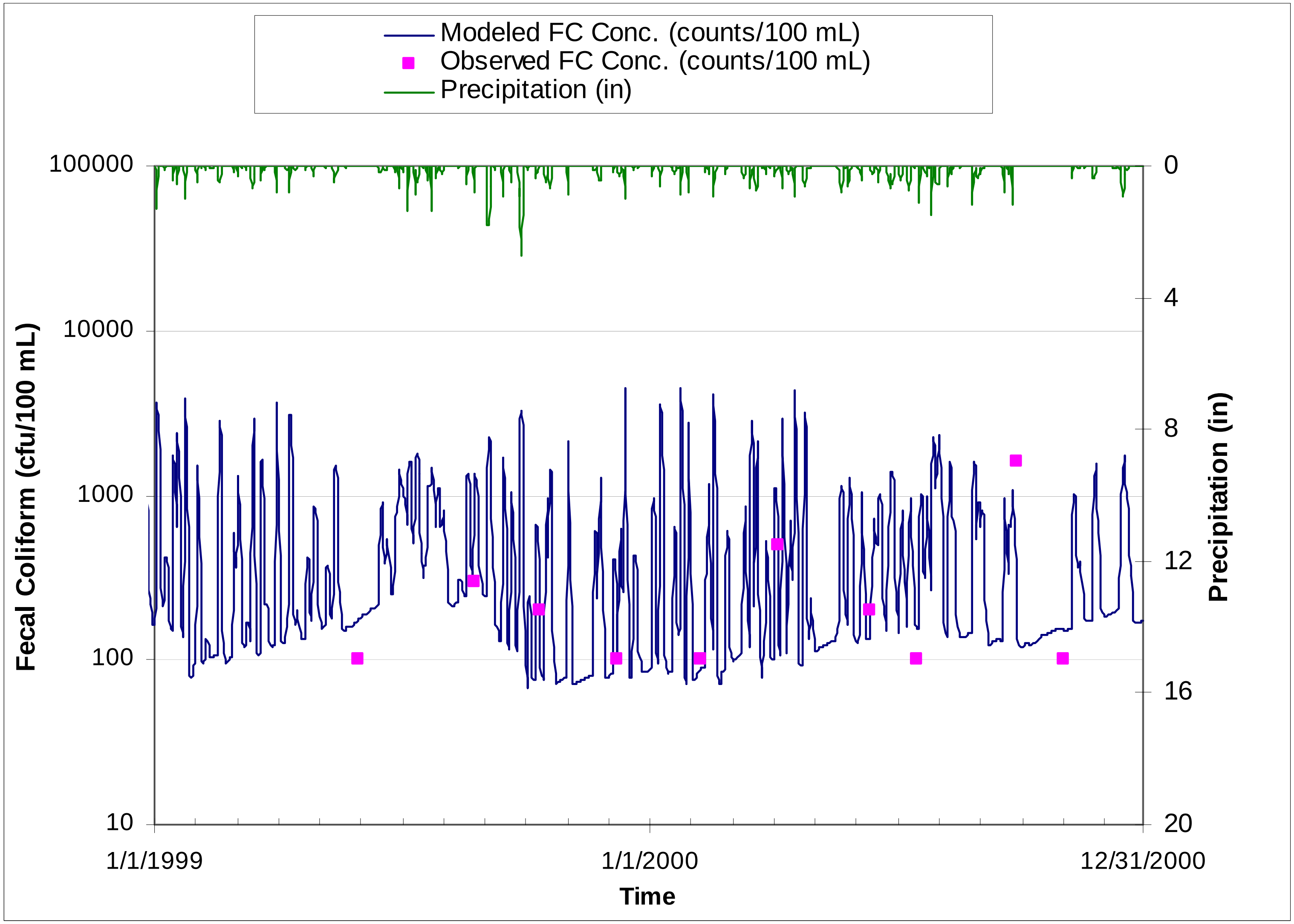
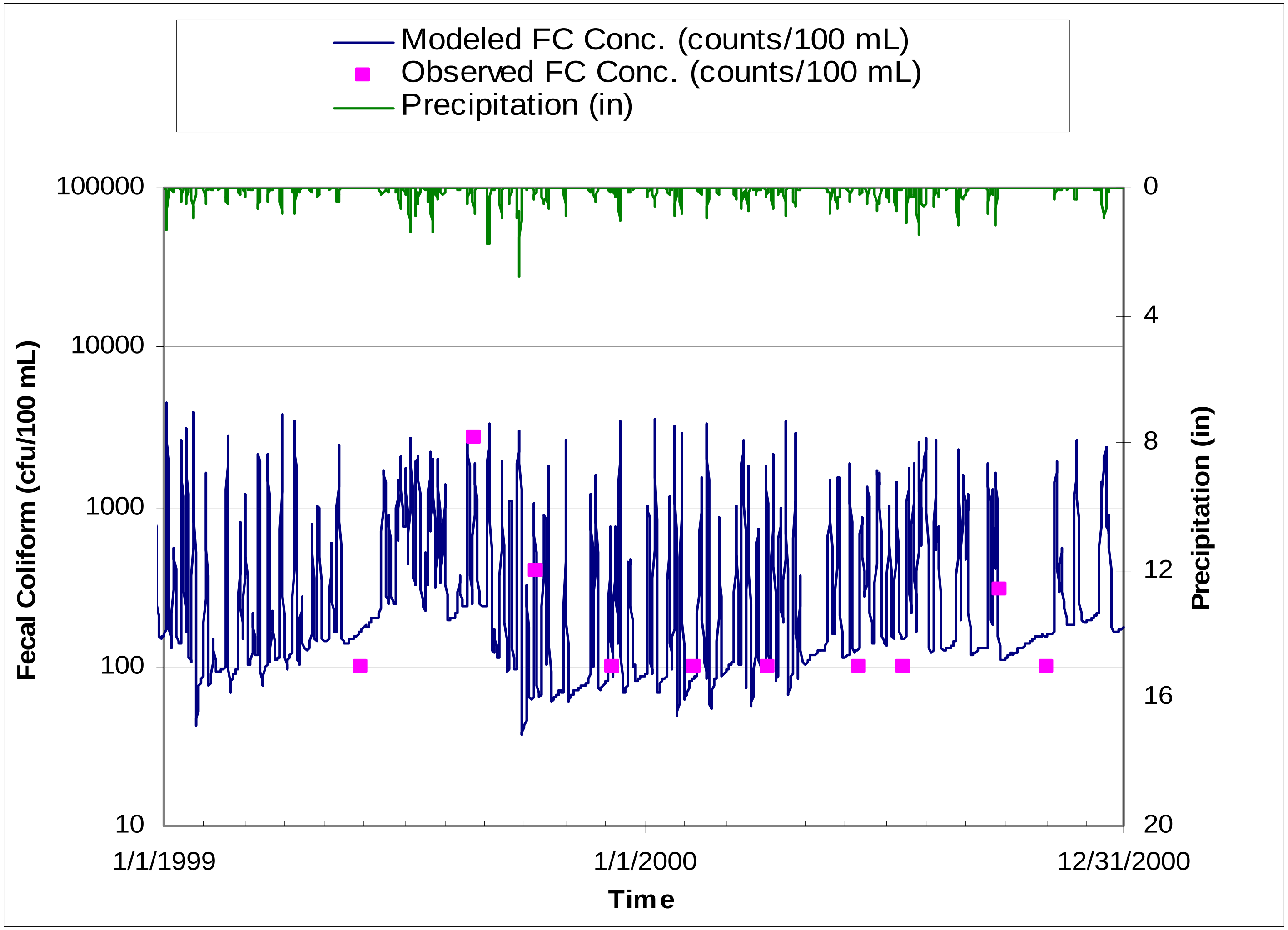


Figure 4-9: Falling River Water Quality Validation (Reach 11)



4.10 Existing Bacteria Loading

The existing fecal coliform loading was calculated based on current watershed conditions. Model input parameters reflected conditions during the period of 1995 to 2000. Figure 4-10 shows the geometric mean fecal coliform concentrations. Figure 4-11 shows the instantaneous fecal coliform concentrations concentrations. Figure 4-10 and 4-11 illustrate that the geometric mean fecal coliform standard of 200 cfu/100 ml and the instantaneous fecal coliform standard of 400 cfu/100 ml were exceeded for the most part during this time period.

Figure 4-10: Fecal Coliform Geometric Mean Existing Conditions in Falling River

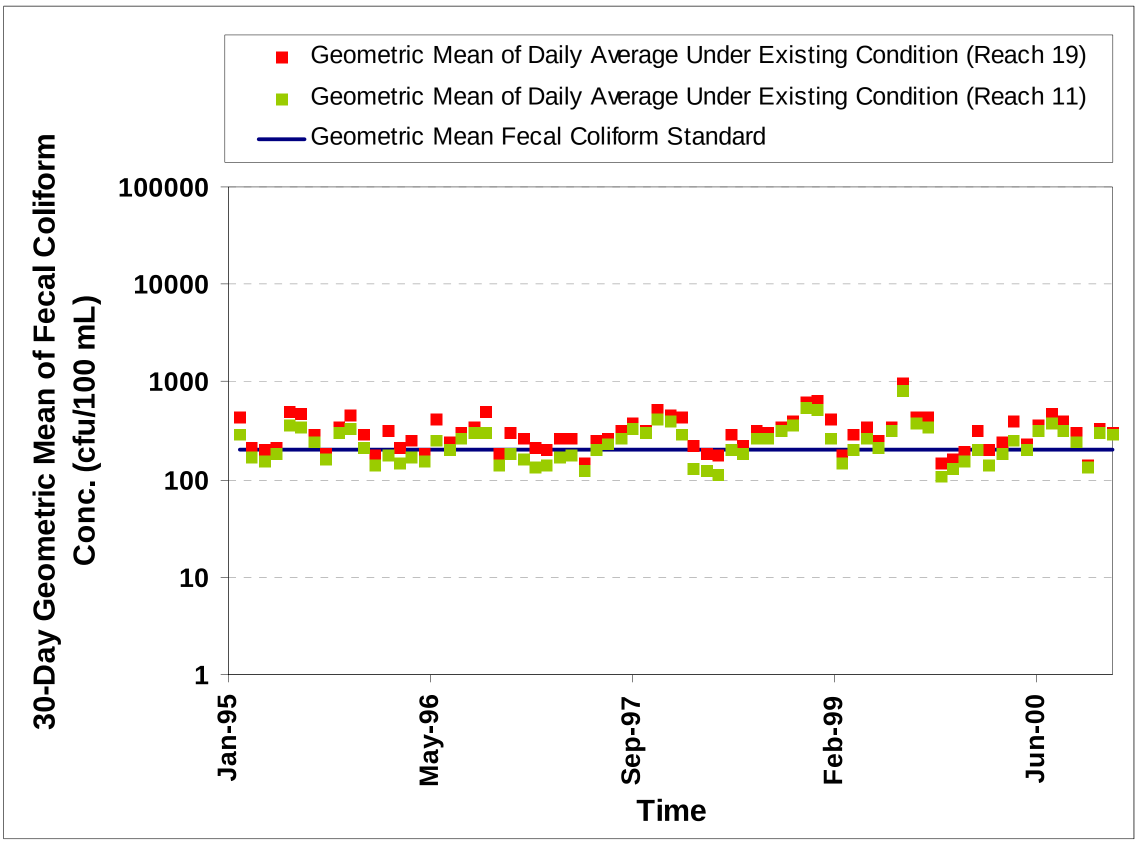
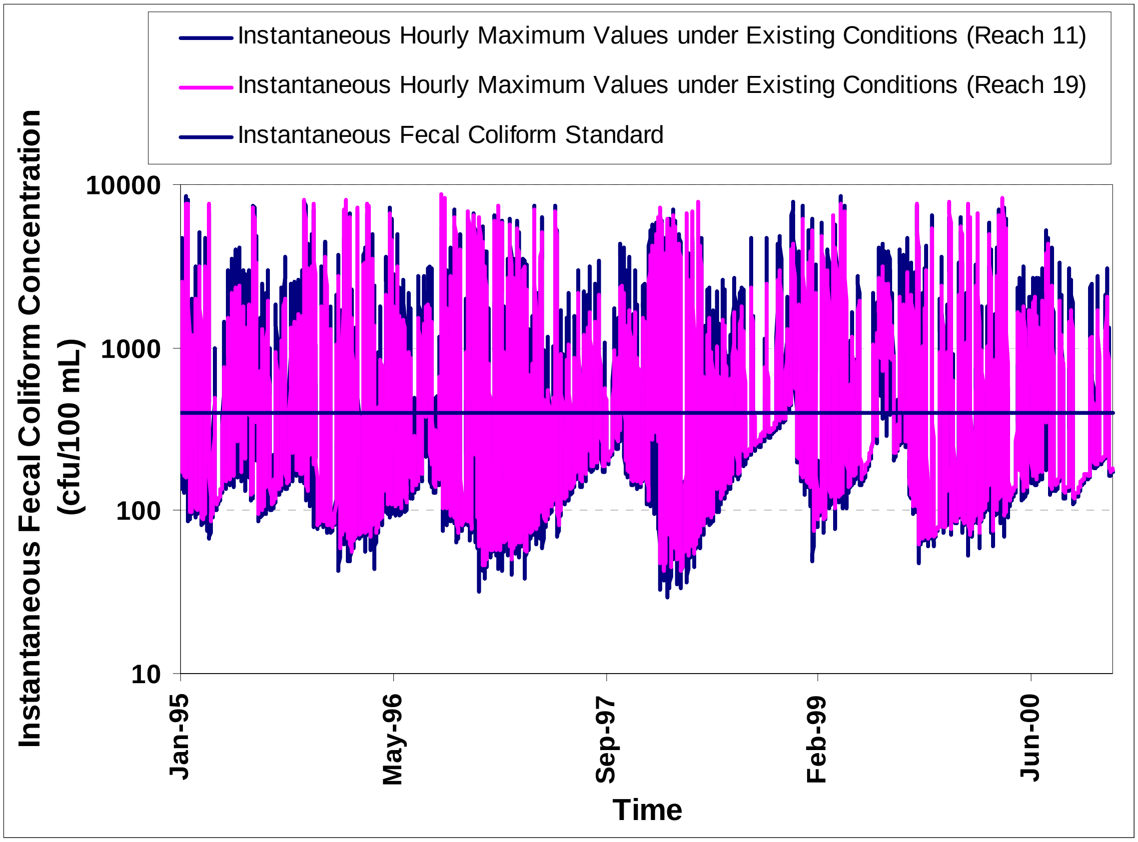


Figure 4-11: Fecal Coliform Instantaneous Existing Conditions in Falling River



Distribution of the existing fecal coliform load by source is presented in Table 4-15. The corresponding E. coli loading is presented in Table 4-16. E. coli concentrations in the impaired Falling River segments (Reach 19 and Reach 11) were calculated from fecal coliform concentrations using a regression based instream translator, which is presented below.

$$\textit{E. coli concentration (cfu/100 ml)} = 2^{-0.0172} \times \textit{(FC concentration (cfu/100ml))}^{0.91905}$$

Table 4-15 and Table 4-16 show that loading from the urban areas and pasturelands are the predominant sources of bacteria in the Falling River watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under dry weather conditions, the direct deposition load from cattle and wildlife will dominate even though their loading is relatively small.

Table 4-15: Fecal Coliform Existing Load Distribution by Source

Source	Annual Average Fecal Coliform Loads	
	cfu/year	Percent (%)
Forest	1.29E+13	0.7%
Cropland	2.75E+13	1.5%
Pasture	1.07E+15	59.4%
Low Residential	5.34E+14	29.7%
Commercial/Industrial	1.72E+11	0.0%
Water/Wetland	2.35E+10	0.0%
Other	5.14E+10	0.0%
Failed Septic	1.95E+11	0.0%
Cattle direct	4.52E+13	2.5%
Wildlife	1.11E+14	6.2%
Point Source	1.36E+12	0.1%
Total	**1.80E+15**	**100%**

Table 4-16: E. coli Existing Load Distribution by Source

Source	Annual Average E. coli Loads	
	cfu/year	Percent (%)
Forest	1.10E+12	1.0%
Cropland	2.22E+12	2.0%
Pasture	6.37E+13	56.6%
Low Residential	3.39E+13	30.1%
Commercial/Industrial	2.09E+10	0.0%
Water/Wetland	3.36E+09	0.0%
Other	6.89E+09	0.0%
Failed Septic	2.35E+10	0.0%
Cattle direct	3.50E+12	3.1%
Wildlife	7.98E+12	7.1%
Point Source	1.40E+11	0.1%
Total	**1.13E+14**	**100%**

5.0 Allocation

For the Falling River bacteria TMDL, allocation analysis was the third stage in development. Its purpose was to develop the framework for reducing bacteria loading under the existing watershed conditions so water quality standards can be met. The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of pollutant sources.

5.1 Incorporation of Margin of Safety

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS will be implicitly incorporated into this TMDL. Implicitly incorporating the MOS will require that allocation scenarios be designed to meet the monthly fecal coliform geometric mean standard of 200 cfu/100 ml and the instantaneous fecal coliform standard of 400 cfu/100 ml with 0% exceedance. In terms of E. coli, incorporating an implicit MOS will require that the allocation scenario be designed to meet the monthly geometric mean standard of 126 cfu/100 ml and the instantaneous standard of 235 cfu/100 ml with 0 violations.

5.2 Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violation, and provides insight and direction in developing the TMDL allocation and implementation. Based on the sensitivity analysis, several allocation scenarios were developed; these are presented in the next section. For each scenario developed, the percent of days water quality conditions violate the monthly geometric mean standard and instantaneous standard for E. coli is shown. The results of the sensitivity analysis are presented in Appendix D.

5.3 Allocation Scenario Development

Allocation scenarios that would reduce the existing fecal coliform load to meet water quality standards were simulated using the HSPF model.

5.3.1 Wasteload Allocation

There are seven permitted facilities discharging in the Falling River watershed; however, only five of the facilities are permitted to discharge bacteria (see Chapter 4). These facilities are authorized to discharge fecal coliform at their permitted E. coli concentration limit of 126 cfu/100mL. For this TMDL, the wasteload allocation for the permitted facilities is to maintain discharge at the design flow and bacteria concentrations at their permitted levels. Table 5-1 shows the loading from the permitted point source discharges in the watershed.

Table 5-1: Falling River Wasteload Allocation for E. coli

Point Source	Existing Load (cfu/day)	Allocated Load (cfu/day)	Percent Reduction
Appomattox STP	2.96E+11	2.96E+11	0%
Town of Brookneal - Lagoon	1.43E+11	1.43E+11	0%
DOC Rustburg	4.87E+10	4.87E+10	0%
Rustburg WWTP	3.48E+11	3.48E+11	0%
Thousand Trails Lynchburg Preserve	6.89E+10	6.89E+10	0%
Total	**9.05E+11**	**9.05E+11**	**0%**

5.3.2 Load Allocation

The reduction of loading from non-point sources, including livestock and wildlife direct deposition, is incorporated into the load allocation. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario. The scenarios considered are presented in Table 5-2. The following is a brief summary of the key scenarios:

- Scenario 0 is the existing load, no reduction of any of the sources.
- Scenario 1 represents elimination of human sources (septic systems and straight pipes).
- Scenario 3 represents elimination of the human sources (septic systems and straight pipes) as well as the direct instream loading from livestock.
- Scenario 4 represents the direct instream loading from wildlife (all other sources are eliminated).

Table 5-2: Falling River Load Allocation Scenarios

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agriculture)	NPS (Urban)	Direct Wildlife
0					
1	100				
2	100	50			
3	100	100			
4	100	100	100	100	
5	100	100			50
6	100	100			75
7	100	100	98	98	50
8	100	100	75	75	88
9	100	100	96	96	63
10	100	100	76	76	90

Fecal coliform loading and instream fecal coliform concentrations were estimated for each potential scenario using the Falling River HSPF model for the hydrologic period of January 1995 to December 2000. The estimated load reductions at Reach 11 and Reach 19 resulting from these allocation scenarios are presented in terms of E. coli in Table 5-3 and Table 5-4, respectively. These tables indicate the percentage of days the 126 cfu/100ml E. coli geometric mean water quality standard and the 235 cfu/100ml E. coli instantaneous water quality standard were violated under each scenario. The following conclusions can be made:

1. In Scenario 0 (existing conditions), the water quality standard was violated most of the time.
2. In Scenario 3, elimination of the human sources (failed septic systems and straight pipes) and the livestock direct instream loading resulted in a 49 percent violation of the E. coli geometric mean standard at Reach 11, and a 67 percent violation of this standard at Reach 19.
3. In Scenario 4, eliminating all sources except direct instream loading from wildlife resulted in a 38 percent violation of the E. coli geometric mean standard at Reach 11, and a 43 percent violation of this standard at Reach 19.

4. No violations of the E. coli geometric mean standard occurred at either reach under Scenario 7, in which there was complete elimination of the human sources (failed septic systems and straight pipes), livestock direct deposition, and 98 percent reduction of urban and agricultural non-point sources, and a 50 percent reduction of direct loading by wildlife.

5. Similarly, Scenario 8 and Scenario 10 did not result in violations of the E. coli geometric mean standard at both Reach 11 and Reach 19. However the instantaneous E. coli standard of 235 cfu/100ml was not met under these scenarios. Scenario 9 did not violate the geometric mean or instantaneous E. coli standards at Reach 19, but did violate the instantaneous standard at Reach 11.

Therefore, Scenario 7 was chosen as the final TMDL load allocation scenario, because this scenario met both the instantaneous and geometric mean E. coli standards.

Table 5-3: Falling River Load Reduction under 30-Day Geometric Mean and Instantaneous Standards for E. coli at Reach 11

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E coli Percent violation of Inst. standard 235 #/100ml
0						60	90
1	100					58	90
2	100	50				53	84
3	100	100				49	81
4	100	100	100	100		38	81
5	100	100			50	18	77
6	100	100			75	6	74
7	100	100	98	98	50	0	0
8	100	100	75	75	88	0	45
9	100	100	96	96	63	0	3
10	100	100	76	76	90	0	45

Table 5-4: Falling River Load Reduction under 30-Day Geometric Mean and Instantaneous Standards for E. coli at Reach 19

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agriculture)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E. coli Percent violation of Inst. standard 235 #/100ml
0						81	100
1	100					79	100
2	100	50				75	97
3	100	100				67	90
4	100	100	100	100		43	90
5	100	100			50	42	90
6	100	100			75	24	90
7	100	100	98	98	50	0	0
8	100	100	75	75	88	0	35
9	100	100	96	96	63	0	0
10	100	100	76	76	90	0	32

5.4 TMDL Summary

Based on the load allocation scenario analysis above, the TMDL allocation plan (Scenario 7) that will meet the 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous water quality standard of 235 cfu/100ml requires:

- 100 percent reduction of the human sources (failed septic systems and straight pipes).
- 100 percent reduction of the direct instream loading from livestock.
- 98 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 50 percent reduction of the direct instream loading from wildlife.

Table 5-5 shows the distribution of the annual average E. coli load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix C.

Table 5-5: Distribution of Annual Average E. Coli Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average E. coli Loads		Percent Reduction (%)
	Existing	Allocation	
Forest	1.94E+13	5.34E+11	97
Low Density Residential	4.94E+14	1.36E+13	97
Pasture	1.25E+15	3.43E+13	97
Cropland	4.34E+13	1.19E+12	97
Commercial/Industrial/Transportation	4.14E+11	1.14E+10	97
Failed Septic/straight Pipes load	3.02E+11	0.00E+00	100
Direct deposition from cattle	4.51E+13	0.00E+00	100
Direct deposition from wildlife	1.03E+14	5.43E+13	47[1]
Point Source (7 permitted facilities)	9.05E+11	9.05E+11	0
Total loads /Overall reduction	**1.96E+15**	**1.05E+14**	**95**

1: Translation from fecal coliform to E. coli standards changed percent reduction by wildlife from 50 to 47 percent.

The resulting geometric mean and instantaneous E. coli concentrations under the TMDL allocation plan are presented in Figure 5-1 and Figure 5-2. Figure 5-1 shows the 30-day geometric mean E. coli loading at Reach 19 and Reach 11 after applying allocation Scenario 7, as well as geometric mean loading under existing conditions. Figure 5-2 shows the instantaneous E. coli loading at Reach 19 and Reach 11 after applying allocation Scenario 7. For both reaches, allocation Scenario 7 results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for E. coli. A summary of the TMDL allocation plan loads for Falling River is presented in Table 5-6.

Table 5-6: Falling River TMDL Allocation Plan Loads (cfu/year) for E. coli

Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
9.05E+11	1.04E+14	Implicit	1.05E+14

Figure 5-1: Geometric Mean E. coli Loadings under Existing Conditions and Allocation Scenario 7

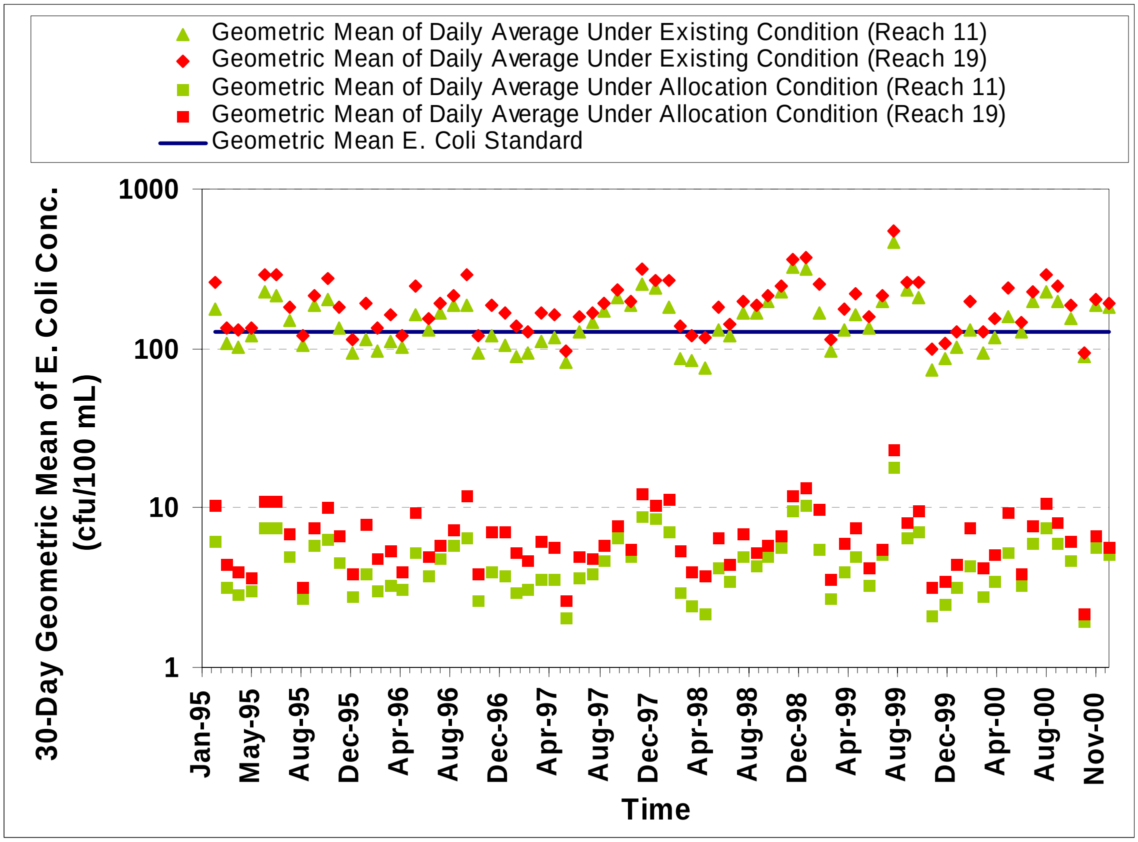
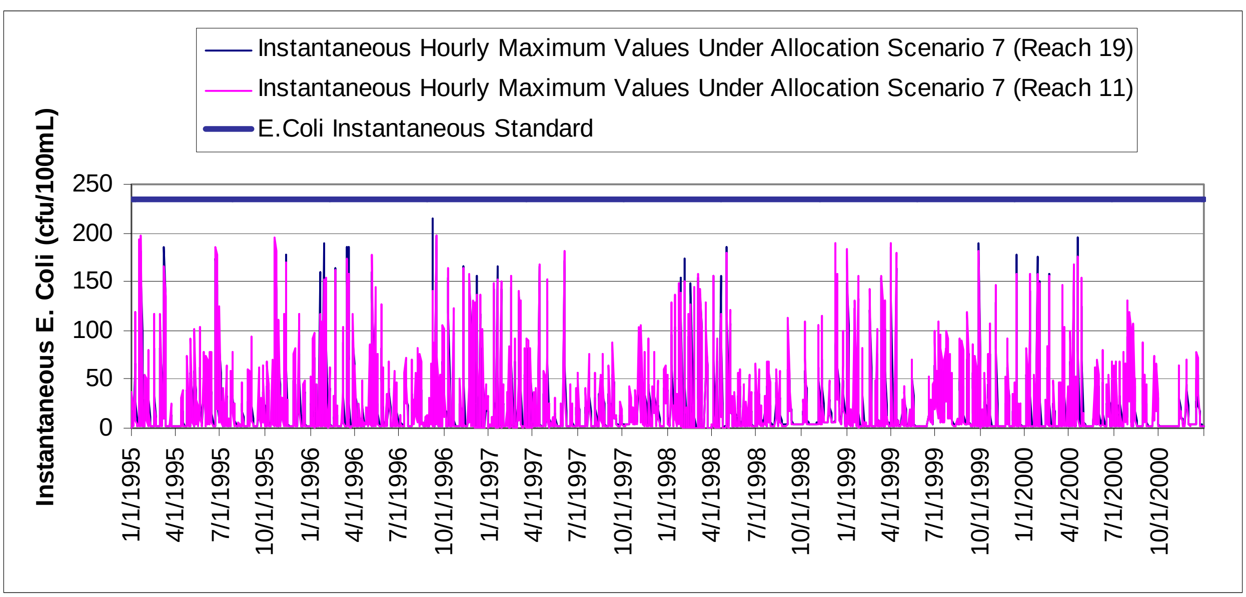


Figure 5-2: Instantaneous E. coli Loadings under Allocation Scenario 7



6.0 TMDL Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria impairments on Falling River. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the recent "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

6.1 Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring.
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling.
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements.
4. It helps ensure that the most cost effective practices are implemented first.
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

6.2 Stage 1 Scenarios

The goal of the stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample maximum criterion

(235 cfu/100mL) are less than 10 percent. The stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios. A margin of safety was not used in determining the stage 1 scenarios. It was estimated for modeling purposes that there are 15 straight pipes in the watershed. Should any be found during the implementation process, they should be eliminated as soon as possible since they would be illegally discharging fecal bacteria into Falling River and its tributaries.

Three scenarios are presented in Table 6-1. Scenario 1 represents the required load reduction that will not exceed the instantaneous standard by more than 10% violation. Scenarios 2 and 3 represent the implementation of BMPs and management strategies such as livestock exclusion from streams, alternative water, manure storage, riparian buffers, and pet waste control that can be readily put in place in the watershed.

Table 6-1: Falling River Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	Reach 11 Percent violation of Inst. standard 235 #/100ml	Reach 19 Percent violation of Inst. standard 235 #/100ml
1	100	100	98	98	5	10%	10%
2	100	100	70	70	0	65%	74%
3	100	100	99	99	0	13%	6%

Under Scenario 1, the E. coli instantaneous standard of 235 cfu/100ml was violated 10 percent of the time at Reach 11 and Reach 19. This condition requires the following reductions:

- ? 100 percent reduction of the human sources (failed septic systems and straight pipes).
- ? 100 percent reduction of the direct instream loading from livestock.
- ? 98 percent reduction of bacteria loading from agricultural and urban non-point sources.
- ? 5 percent reduction of the direct instream loading from wildlife.

6.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Falling River watershed.

6.4 Reasonable Assurance for Implementation

6.4.1 Follow-Up Monitoring

VADEQ will continue monitoring 4-AFRV002.78, 4-AFRV010.99, 4-AFRV017.71, 4-APLP000.40, and 4-AMEY016.00 in accordance with its ambient monitoring program to evaluate reductions in fecal bacteria counts and the effectiveness of TMDL implementation in attainment of water quality standards.

Monitoring stations 4-AFRV002.78, 4-AFRV010.99, and 4-AMEY016.00 are trend stations and will continue to be monitored on a monthly basis. The other stations are watershed stations with bi-monthly monitoring for a two-year period occurring every six years.

6.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

6.4.3 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Non-point Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.4.4 Addressing Wildlife Contributions

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. As is the case for Falling River, these streams may not be able to attain standards without some reduction in wildlife load. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** While managing overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address this issue, Virginia has proposed (during its recent triennial water quality standards review) a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria became effective in February 2004 and can be found at http://www.deq.state.va.us/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of bacterial contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for non-point source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.state.va.us/wqs/WQS03AUG.pdf.

Based on the above, EPA and Virginia have developed a process to address the wildlife issue. First in this process is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of overpopulations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in section 6.1 above. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

7.0 Public Participation

The development of the Falling River TMDL would not have been possible without public participation. Three public meetings were held in the Falling River watershed, the following is a summary of the meeting objectives and attendance.

TAC Meeting. The TAC meeting was held in the Town of Brookneal on April 8, 2003 to discuss the process for TMDL development, present the listed segment of Falling River and present the data that caused the segment to be on the 303(d) list, identify review the data and information needed in the TMDL development, and officially request data and information. Thirteen people representing the various State and local government agencies attended this meeting. Copies of the presentation materials were available for public distribution. The meeting participants were contacted by DEQ via Email and phone.

Public Meeting No. 1. The first public meeting was held in the Town of Brookneal on October 22, 2003 to present the following:

- listed segments of Falling River,
- the data that caused the segments to be on the 303(d) list,
- review the TMDL process;
- the livestock, wildlife, and pet inventories;
- the fecal coliform sources assessment
- the calculation used to estimate the total available fecal coliform load;
- explain the assumptions used in the calculations; and present the HSPF model.

Fourteen people attended the meeting. Copies of the presentation were available for public distribution. The meeting was public noticed in *The Virginia Register of Regulations*. During the 30-day comment period, no written comments were received.

Public Meeting No. 2. The Second public meeting was held in the Town of Brookneal on February 24, 2004 to discuss the sources assessment, present the HSPF model calibration and the goodness of fit, and discuss the Draft TMDL. Twenty people attended the meeting. Copies of the presentation and the draft TMDL report executive summary were available for public distribution. The meeting was public noticed in *The Virginia Register of Regulations.*

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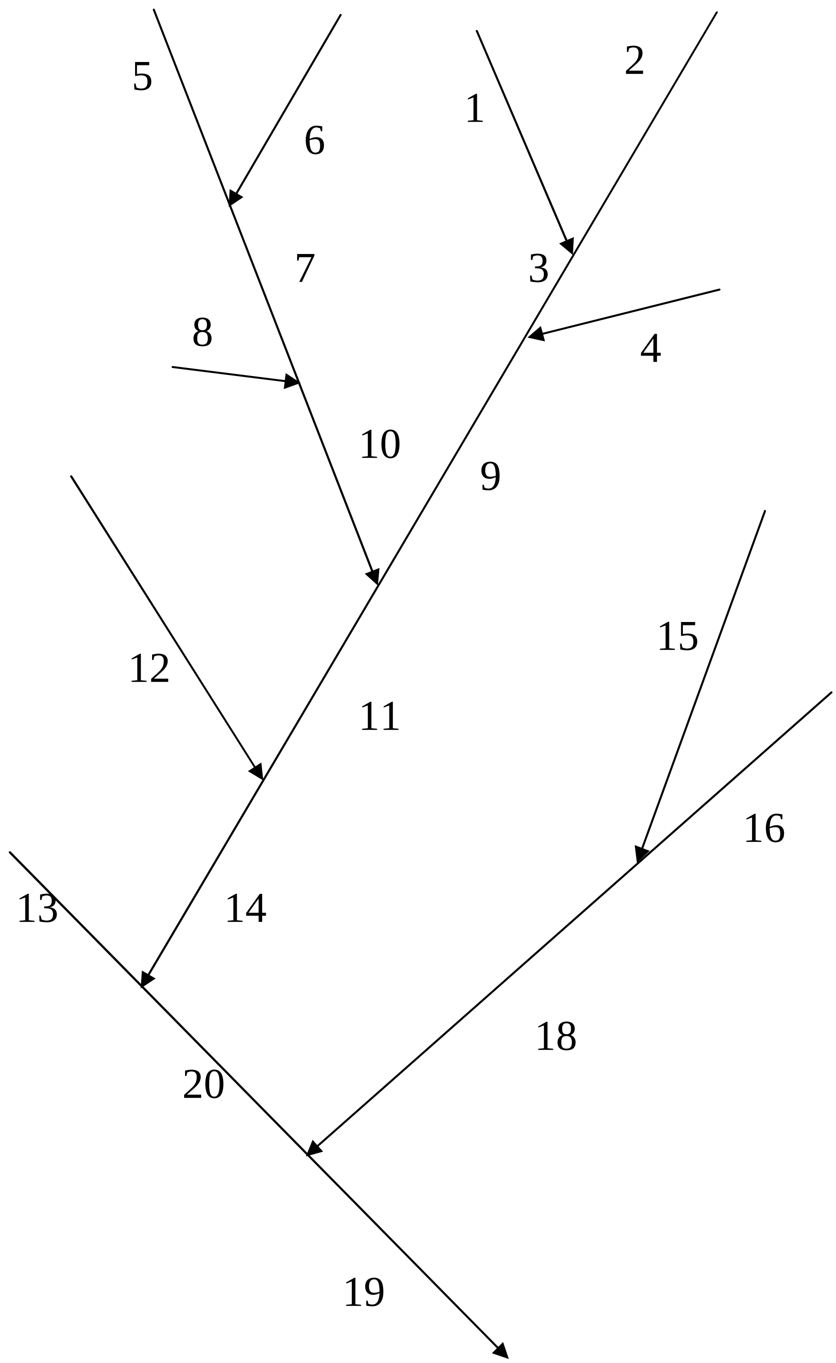
Appendix A

Model Representation of Stream Reach Networks



Model representation of Falling River Model
Stream Network

Appendix B

Monthly Fecal Coliform Build-up Rates

Table B-1: Falling River Monthly Build-up rates cfu/ac/day

Land use	Jan	Feb	Mar	Apr	May	Jun
Forest	2.34E+07	2.34E+07	2.34E+07	2.34E+07	2.34E+07	2.34E+07
Cropland	2.33E+07	1.08E+09	9.68E+08	2.02E+09	6.53E+08	1.70E+09
Pasture	4.07E+09	4.40E+09	4.38E+09	4.72E+09	4.31E+09	4.64E+09
Low Intensity Resid.	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10
Comm/Ind/Trnsprt	8.61E+07	8.61E+07	8.61E+07	8.61E+07	8.61E+07	8.61E+07
High Intensity Resid.	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10

Table B-2: Falling River Monthly Build-up rates cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Forest	2.34E+07	2.34E+07	2.34E+07	2.34E+07	2.34E+07	2.34E+07
Cropland	6.53E+08	1.70E+09	9.68E+08	2.02E+09	1.06E+09	2.33E+07
Pasture	4.32E+09	4.65E+09	4.42E+09	4.74E+09	4.44E+09	4.10E+09
Low Intensity Resid.	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10
Comm/Ind/Trnsprt	8.61E+07	8.61E+07	8.61E+07	8.61E+07	8.61E+07	8.61E+07
High Intensity Resid.	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10	3.38E+10

Table B-3 Falling River Monthly Direct Deposition Rates

Month	Cattle (cfu/month)	Wildlife (cfu/month)	Human (cfu/month)
1	3.08E+07	9.40E+12	1.05E+10
2	2.78E+07	8.49E+12	9.44E+09
3	3.08E+07	9.40E+12	1.05E+10
4	2.98E+07	9.09E+12	1.01E+10
5	3.09E+07	9.40E+12	1.05E+10
6	2.99E+07	9.09E+12	1.01E+10
7	3.09E+07	9.40E+12	1.05E+10
8	3.09E+07	9.40E+12	1.05E+10
9	2.99E+07	9.09E+12	1.01E+10
10	3.10E+07	9.40E+12	1.05E+10
11	3.00E+07	9.09E+12	1.01E+10
12	3.10E+07	9.40E+12	1.05E+10

Appendix C

Monthly Distribution of Fecal Coliform Loading Under Existing and Allocated Conditions

Table C-1 **Fecal Coliform Load: Existing Condition (counts/ month)**

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	High Density Residential
1	4.16E+12	6.72E+12	3.79E+14	1.28E+14	6.23E+10	7.00E+09	1.48E+11
2	2.81E+12	6.50E+12	2.54E+14	8.27E+13	3.97E+10	7.10E+09	1.07E+11
3	3.65E+12	1.16E+13	3.35E+14	1.04E+14	5.07E+10	8.05E+09	1.43E+11
4	2.84E+12	8.62E+12	2.69E+14	8.42E+13	4.01E+10	5.01E+09	1.21E+11
5	9.15E+11	1.42E+12	8.63E+13	3.36E+13	1.40E+10	2.53E+09	4.05E+10
6	6.27E+11	2.24E+12	6.15E+13	2.60E+13	9.91E+09	1.72E+09	2.31E+10
7	9.22E+10	3.38E+11	1.22E+13	1.54E+13	3.59E+09	1.03E+09	1.93E+09
8	1.05E+11	3.70E+11	1.20E+13	1.31E+13	3.39E+09	9.84E+08	2.26E+09
9	1.86E+12	6.11E+12	1.69E+14	5.37E+13	2.39E+10	2.12E+09	5.43E+10
10	5.04E+11	1.98E+12	4.54E+13	1.85E+13	8.16E+09	1.96E+09	1.88E+10
11	7.81E+11	1.27E+12	7.67E+13	3.49E+13	1.47E+10	1.88E+09	3.49E+10
12	1.37E+12	3.29E+11	1.19E+14	4.81E+13	2.12E+10	3.40E+09	5.44E+10

Table C-2 **Fecal Coliform Load: Allocation Run (counts/ month)**

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	High Density Residential
1	1.66E+11	2.69E+11	1.52E+13	5.13E+12	2.49E+09	2.80E+08	5.91E+09
2	1.12E+11	2.60E+11	1.01E+13	3.31E+12	1.59E+09	2.84E+08	4.28E+09
3	1.46E+11	4.66E+11	1.34E+13	4.18E+12	2.03E+09	3.22E+08	5.73E+09
4	1.14E+11	3.45E+11	1.07E+13	3.37E+12	1.61E+09	2.00E+08	4.83E+09
5	3.66E+10	5.69E+10	3.45E+12	1.35E+12	5.61E+08	1.01E+08	1.62E+09
6	2.51E+10	8.95E+10	2.46E+12	1.04E+12	3.96E+08	6.87E+07	9.23E+08
7	3.69E+09	1.35E+10	4.87E+11	6.17E+11	1.43E+08	4.11E+07	7.72E+07
8	4.20E+09	1.48E+10	4.80E+11	5.24E+11	1.35E+08	3.93E+07	9.02E+07
9	7.44E+10	2.45E+11	6.77E+12	2.15E+12	9.56E+08	8.48E+07	2.17E+09
10	2.01E+10	7.92E+10	1.81E+12	7.38E+11	3.27E+08	7.86E+07	7.51E+08
11	3.13E+10	5.10E+10	3.07E+12	1.40E+12	5.86E+08	7.51E+07	1.40E+09
12	5.49E+10	1.31E+10	4.75E+12	1.92E+12	8.48E+08	1.36E+08	2.18E+09

Appendix D

Sensitivity Analysis

Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violation and provides insight and direction in developing the TMDL allocation and implementation. Falling River flows through a rural setting. Potential sources of fecal coliform include non-point (land-based) sources such as runoff from livestock grazing, manure and biosolids land application, residential waste from failed septic systems or straight pipes, and wildlife. Some of these sources are dry weather driven and others are wet weather driven.

The objective of the sensitivity analysis was to assess the impacts of variation of model calibration parameters on the simulation of flow and the violation of the fecal coliform standard in Falling River. For the January 1997 to December 2000 period, the model was run with 110 percent and 90 percent of calibrated values of the parameters. The scenarios that were analyzed include the following:

- 10 percent increase in LZSN
- 10 percent decrease in LZSN
- 10 percent increase in INFILT
- 10 percent decrease in INFILT
- 10 percent increase in AGWRC
- 10 percent decrease in AGWRC
- 10 percent increase in UZSN
- 10 percent decrease in UZSN
- 10 percent increase in INTFW
- 10 percent decrease in INTFW
- 10 percent increase in IRC
- 10 percent decrease in IRC
- 10 percent increase in LZETP
- 10 percent decrease in LZETP

The modeled flows for different sensitivity runs were compared with observed flows at the gage and the coefficients of determination of the hydrologic sensitivity analysis are presented in Table D-1. Based on these tables it can be seen that the calibration parameters affect the coefficient of determination in the decreasing order of UZSN, INTFW, LZSN, INFILT, AGWRC, IRC and LZETP.

The sensitivity analysis was also performed for two water quality parameters, WSQOP and FSTDEC, by simulating the fecal coliform concentrations for 120 percent and 80 percent of their calibrated values. The rate of violation of the Monthly Geometric Mean Water Quality Standard was determined for each scenario and compared with the rate of violation under the water quality calibration run. The changes in the rate of violation are presented in Table D-2. The results of the sensitivity analysis show that WSQOP has a more pronounced effect on the violation of the water quality standards than FSTDEC.

Table D-1. Sensitivity Analysis: Variation in Coefficient of Determination With Respect to Variation in Parameters For Simulation Period 1997-2000

Parameter	Coefficient of Determination	
	+10% change in parameter	-10% change in parameter
LZSN	0.839	0.842
INFILT	0.838	0.841
AGWRC	0.840	0.837
UZSN	0.832	0.846
INTFW	0.844	0.842
IRC	0.840	0.840
LZETP	0.840	0.840
Calibrated Parameters 0.840		

Table D-2. Sensitivity Analysis: Change in Violation Rate From 20% Change in Calibration Parameter Values

	WSQOP		FSTDEC	
Segment #	+20%	-20%	+20%	-20%
11	-0.04	0.01	0.00	0.00
19	-0.03	0.04	0.00	0.00